

Network Systems  
Science & Advanced  
Computing  
Biocomplexity Institute  
& Initiative  
University of Virginia

# Estimation of COVID-19 Impact in Virginia

May 26<sup>th</sup>, 2021

(data current to May 22<sup>nd</sup> – May 25<sup>th</sup>)

Biocomplexity Institute Technical report: TR 2021-064



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**BIOCOMPLEXITY** INSTITUTE

[biocomplexity.virginia.edu](https://biocomplexity.virginia.edu)

# About Us

- Biocomplexity Institute at the University of Virginia
  - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
  - Pandemic response for Influenza, Ebola, Zika, and others



## Points of Contact

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# Overview

- **Goal:** Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
  - Calibrate explanatory mechanistic model to observed cases
  - Project based on scenarios for next 4 months
  - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
  - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
  - Geographic spread over time, case counts, healthcare burdens

# Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

Even without perfect projections, we can confidently draw conclusions:

- **Case rates in Virginia continue to decline with pace accelerating in some districts**
- VA mean weekly incidence down to 4/100K from 6/100K, US down (8 from 10 per 100K)
- Vaccination rates have slowed considerably, but population immunity now estimated over 65%
- Projections show declining rate overall across Commonwealth
- Recent updates:
  - Minor updates to measured acceptance levels and adjusted vaccination scenarios
  - Additional Fall resurgence study scenario testing resilience of population
  - Limited waning of natural immunity included in fit and projections, also with seroprevalence update

The situation continues to change. Models continue to be updated regularly.

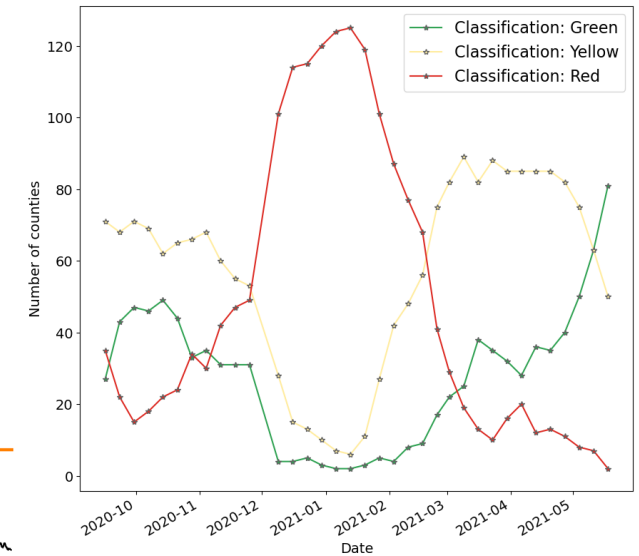
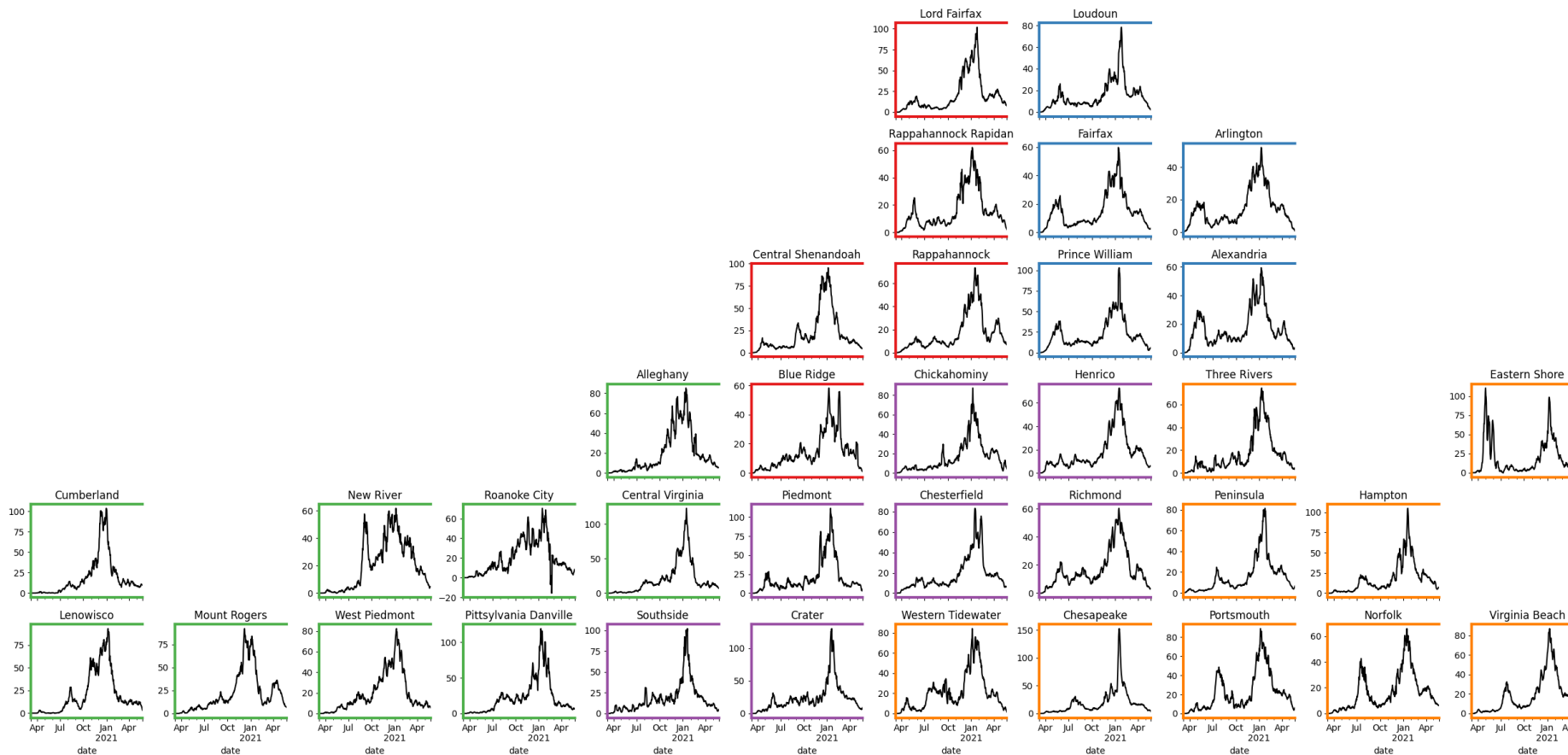




# Situation Assessment

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# Case Rates (per 100k) and Test Positivity



<https://data.cms.gov/stories/s/q5r5-gjyu>

## County level test positivity from RT-PCR tests.

**Green:** <5.0%

(or with <20 tests in past 14 days)

**Yellow:** 5.0%-10.0%

(or with <500 tests and <2000 tests/100k and >10% positivity over 14 days)

**Red:** >10.0%

(and not "Green" or "Yellow")

# District Trajectories

**Goal:** Define epochs of a Health District's COVID-19 incidence to characterize the current trajectory

**Method:** Find recent peak and use hockey stick fit to find inflection point afterwards, then use this period's slope to define the trajectory

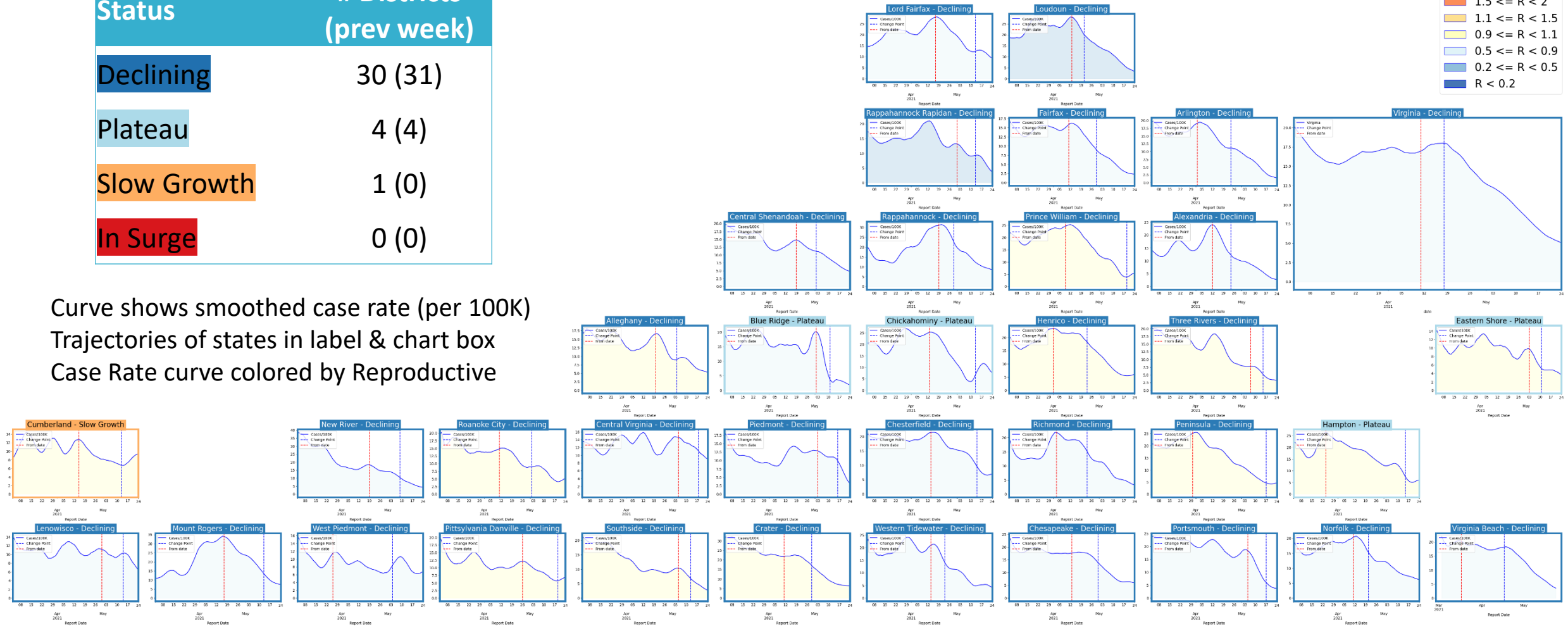


Trajectory	Description	Weekly Case Rate (per 100K) bounds	# Districts (prev week)
<b>Declining</b>	Sustained decreases following a recent peak	below -0.9	31 (31)
<b>Plateau</b>	Steady level with minimal trend up or down	above -0.9 and below 0.5	2 (4)
<b>Slow Growth</b>	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5	2 (0)
<b>In Surge</b>	Currently experiencing sustained rapid and significant growth	2.5 or greater	0 (0)

# District Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	30 (31)
Plateau	4 (4)
Slow Growth	1 (0)
In Surge	0 (0)

Curve shows smoothed case rate (per 100K)  
Trajectories of states in label & chart box  
Case Rate curve colored by Reproductive



# Estimating Daily Reproductive Number

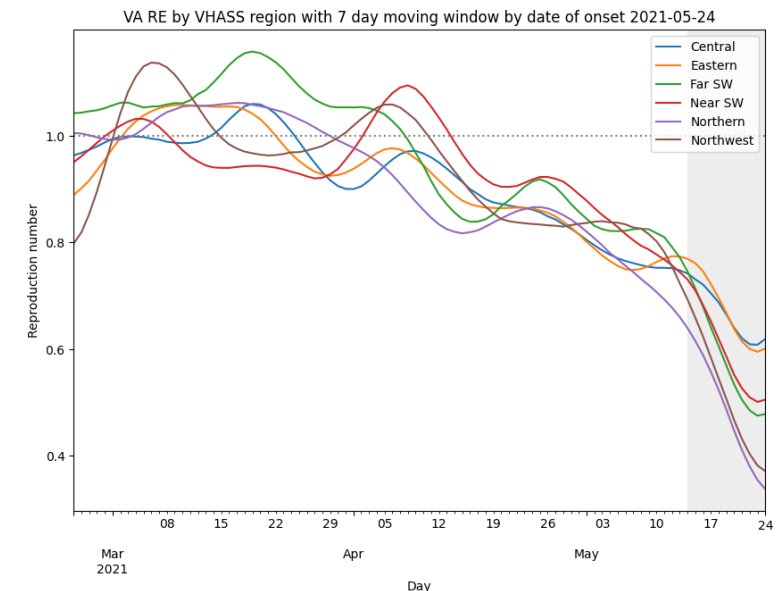
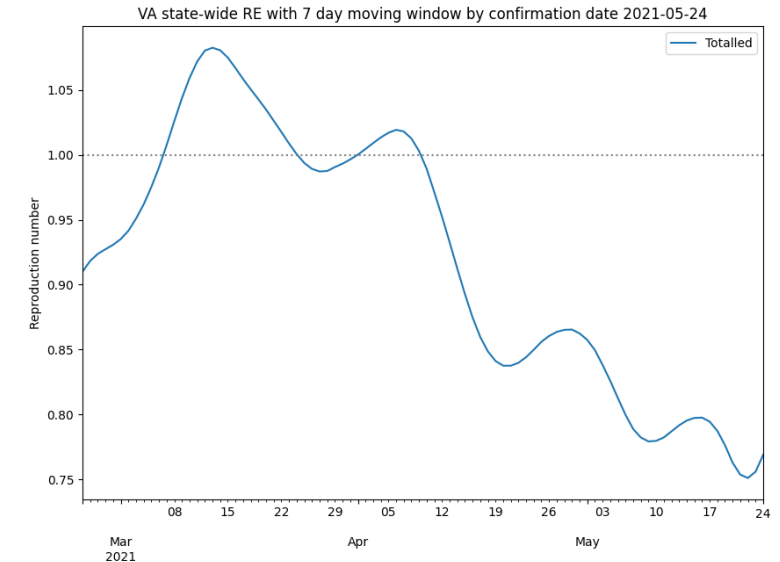
## May 24<sup>th</sup> Estimates

Region	Date Confirmed $R_e$	Date Confirmed Diff Last Week
State-wide	0.769	0.072
Central	0.821	0.019
Eastern	0.815	0.121
Far SW	0.805	0.054
Near SW	0.823	0.112
Northern	0.748	0.181
Northwest	0.688	-0.189

### Methodology

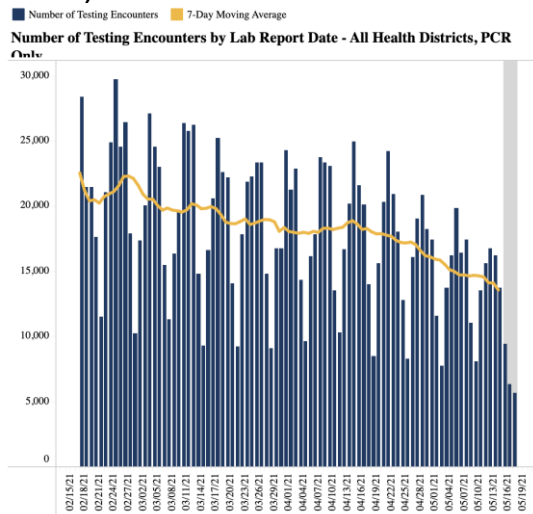
- Wallinga-Teunis method (EpiEstim<sup>1</sup>) for cases by confirmation date
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, <https://doi.org/10.1093/aje/kwt133>

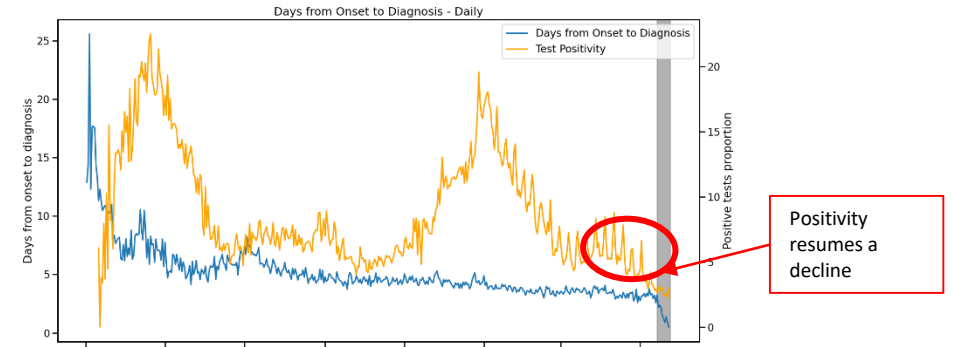


# Changes in Case Detection

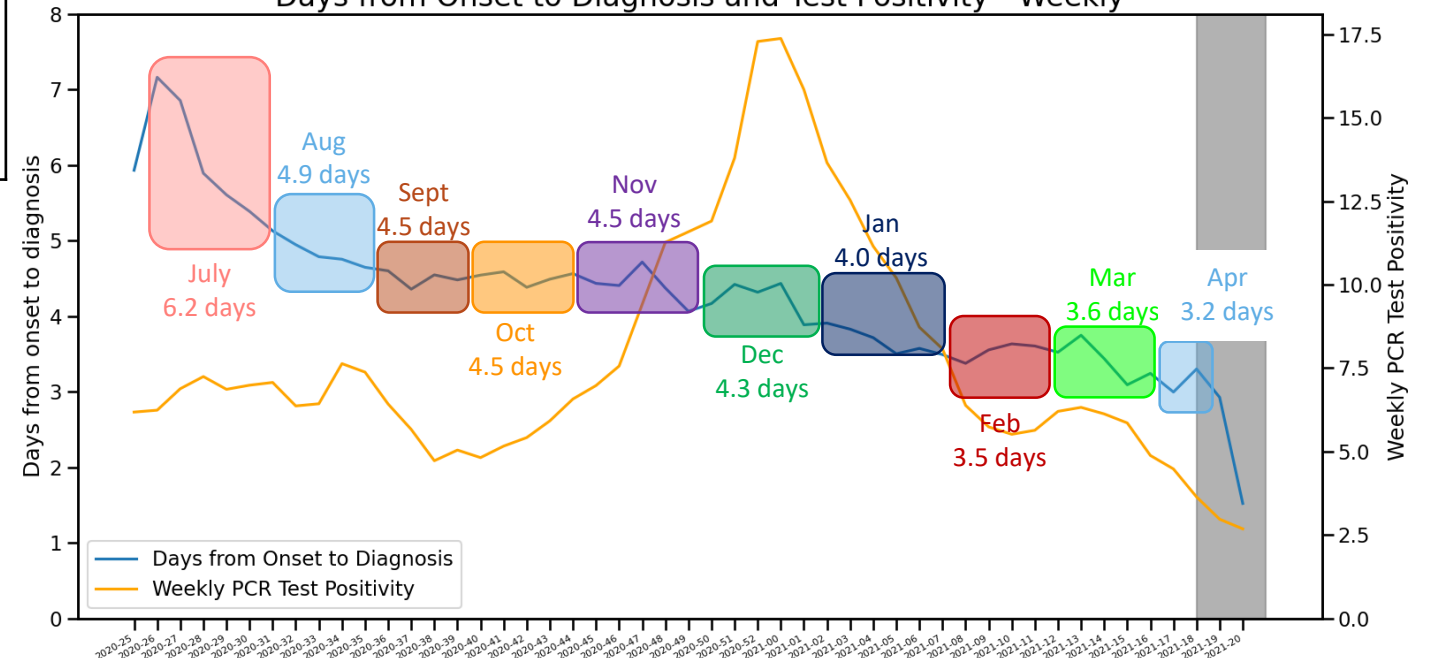
Timeframe (weeks)	Mean days	% difference from overall mean
July (26-30)	6.2	-2%
Aug (31-34)	4.9	-22%
Sept (35-38)	4.5	-28%
Oct (39-43)	4.5	-29%
Nov (44-47)	4.5	-28%
Dec (48-49)	4.3	-32%
Jan (00-04)	4.0	-37%
Feb (05-08)	3.5	-45%
Mar (09-13)	3.6	-43%
Apr (14-18)	3.2	-49%
Overall (13 - 18)	6.3	--



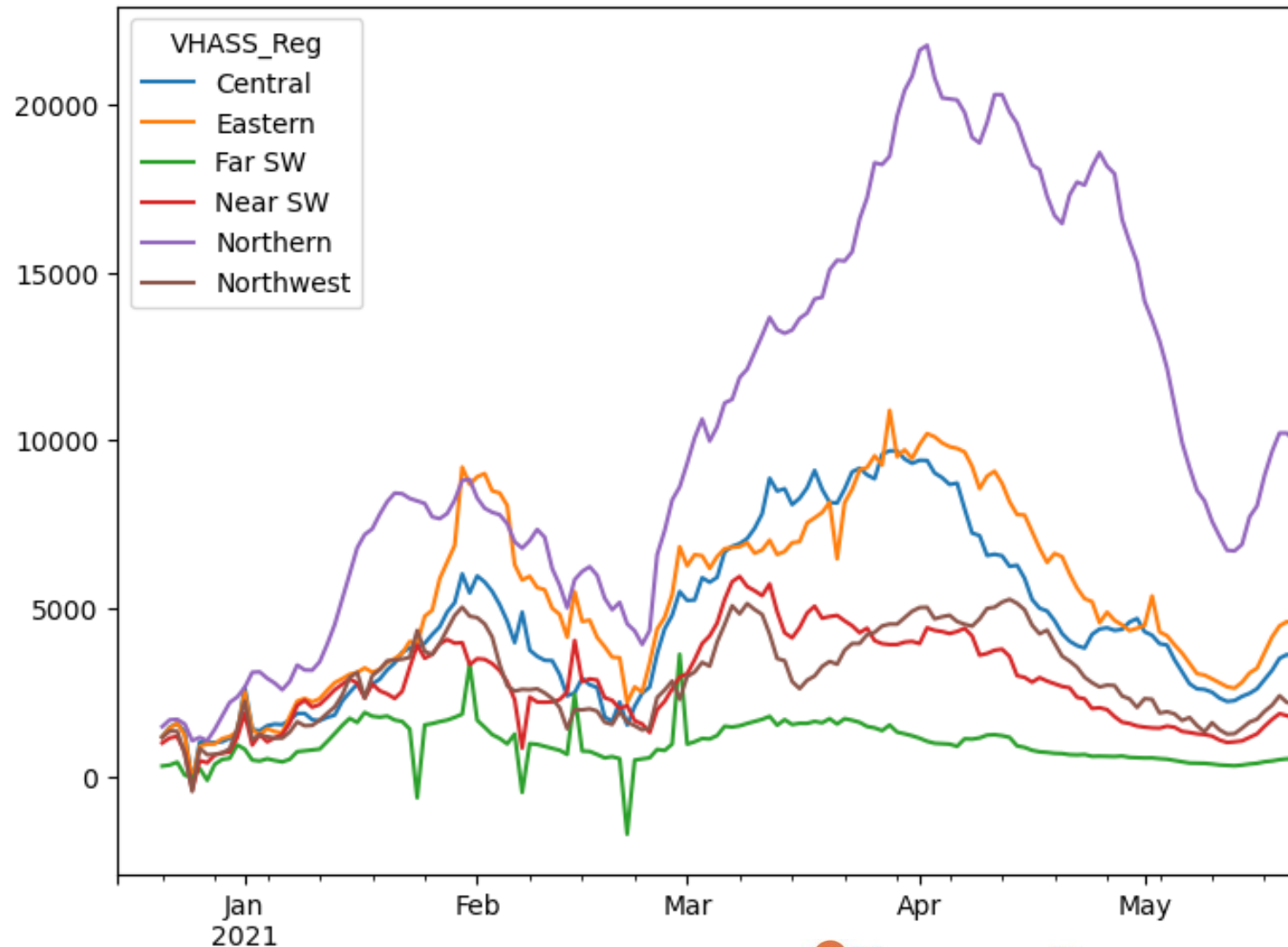
Test positivity vs. Onset to Diagnosis



Days from Onset to Diagnosis and Test Positivity - Weekly

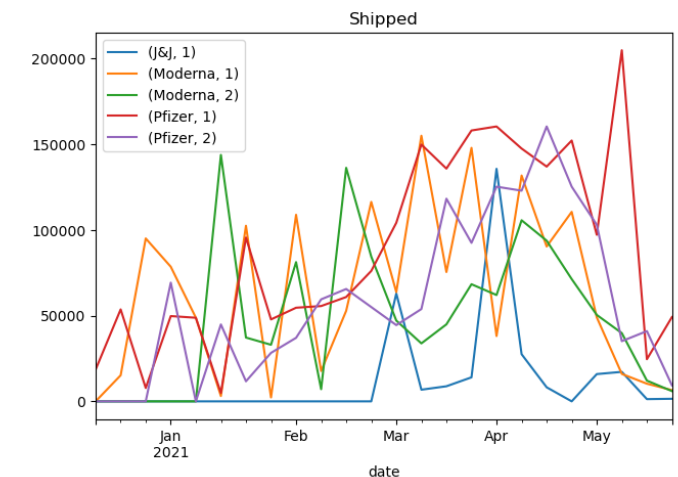


# Vaccination Administration Slows



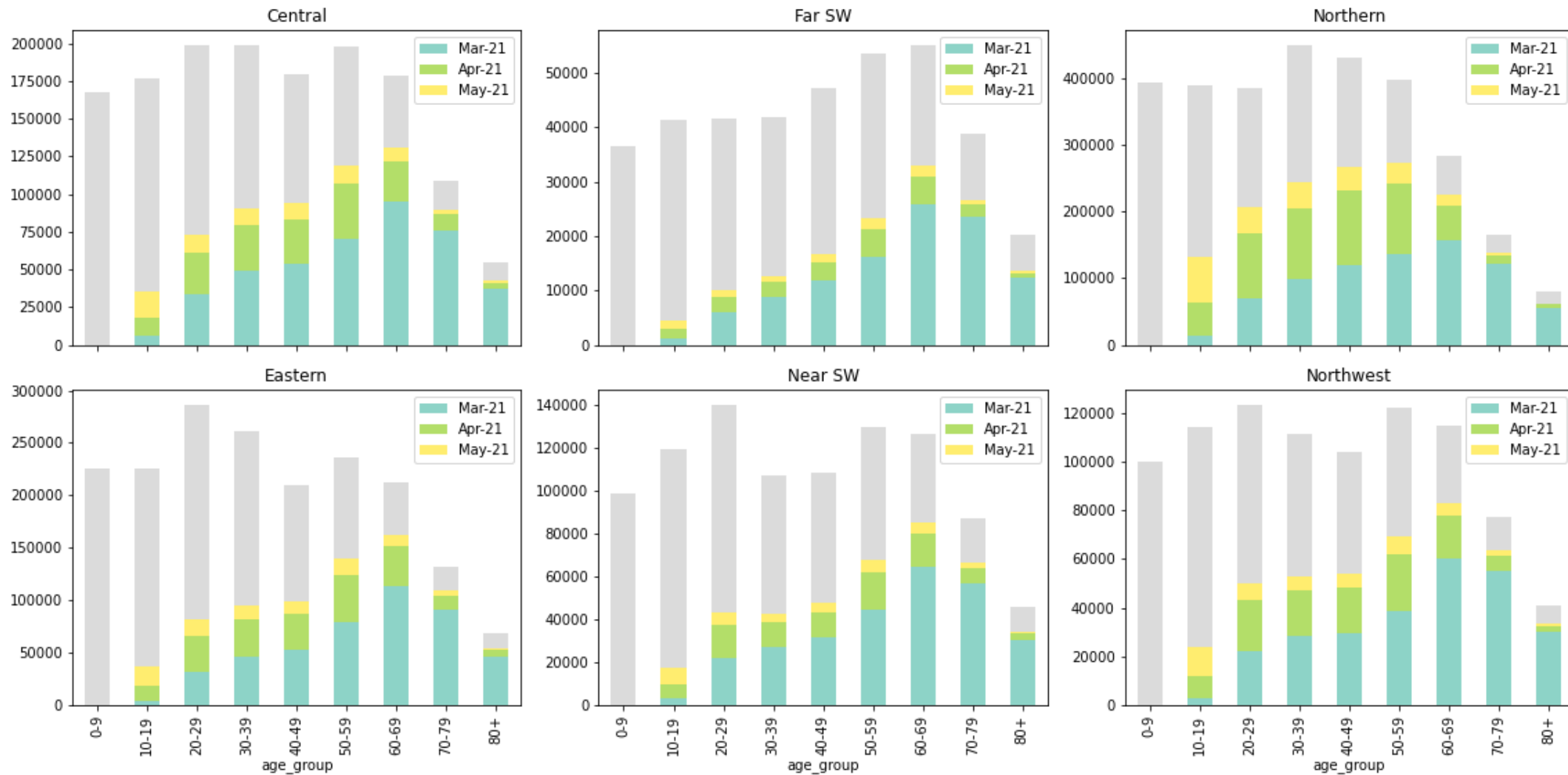
## Regional Vaccine courses initiated per day:

- Total counts of first dose of vaccines across regions
- Recent rise due to opening of vaccinations to 12-16 year olds



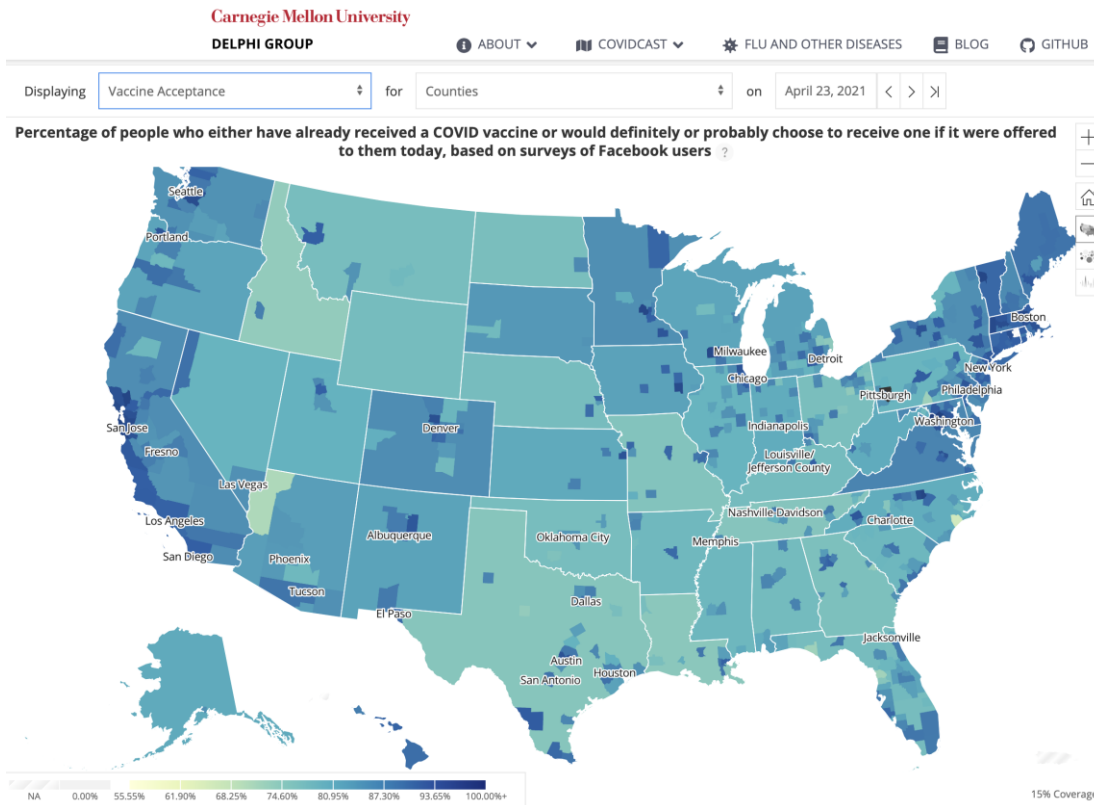
Shipments have slowed with decreased demand

# Vaccinations Shift to Younger Populations





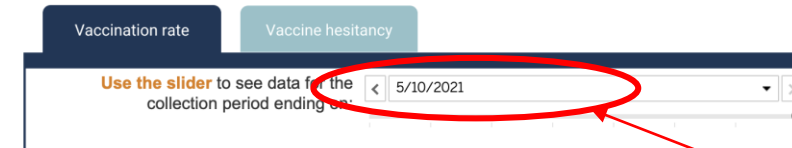
# Vaccine Acceptance Data Sources



## COVIDcast / Facebook Survey

<https://covidcast.cmu.edu>

## Household Pulse Survey COVID-19 Vaccination Tracker

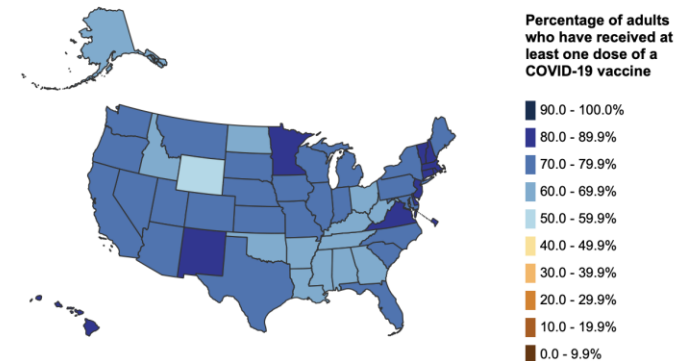


**74.6%**  
(+/- 0.5%)  
**98.4%**  
(+/- 0.1%)

of U.S. adults 18 years and older have received at least one dose of a COVID-19 vaccine.

of those who have received at least one dose of a vaccine have received or plan to receive all required doses.

Estimated Vaccination Rates by State: April 28 - March 10, 2021  
Hover over a state to view the percentage of vaccinated adults in that state.



## Census Household Pulse Surveys (HPS)

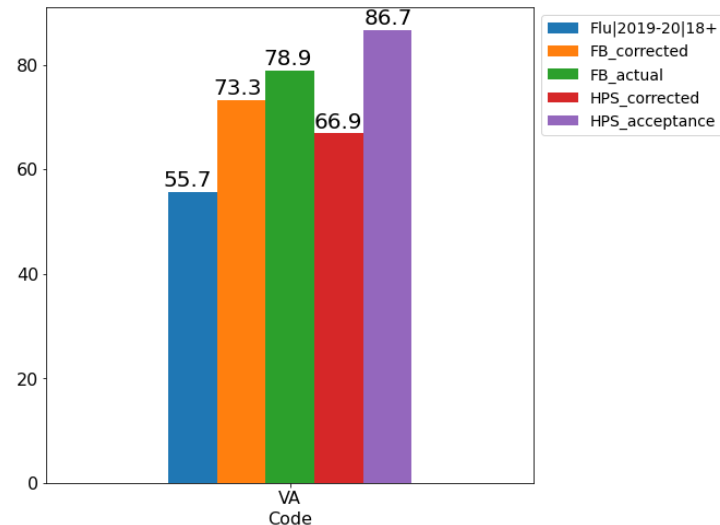
<https://www.census.gov/library/visualizations/interactive/household-pulse-survey-covid-19-vaccination-tracker.html>

# Vaccination Acceptance – Comparison of Sources

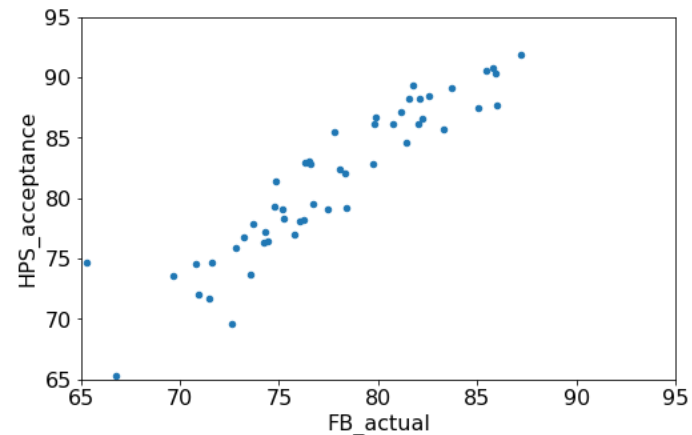
## Measured acceptance varies across sources:

- **COVIDcast / Facebook (FB):** Both corrected and actual measurement
- **FluVax:** Acceptance levels in VA for influenza vaccine during 2019-20 flu season
- **Household Pulse (HPS):** Census administered survey, but with some time delay till release (most recent for fortnight ending May 10<sup>th</sup>, 2021)
- HPS has highest overall, while FluVax is expectedly the lowest
- Corrected HPS and COVIDcast are very similar for VA at the state level, and approach FluVax

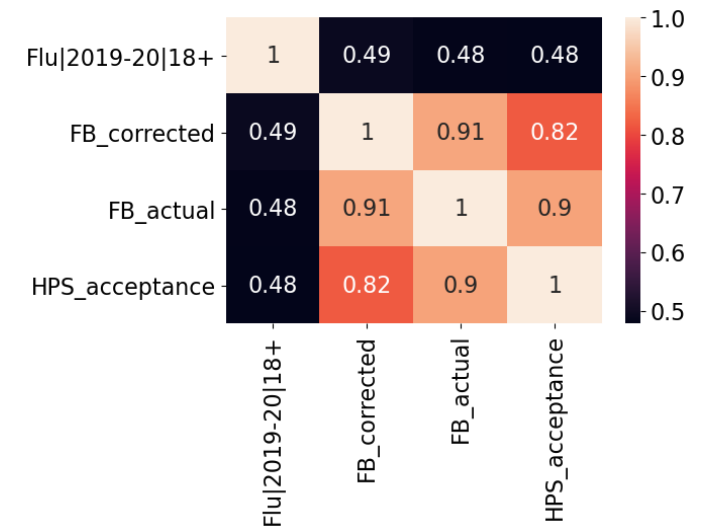
## Virginia Vaccine Acceptance levels



## State by State correlation COVIDcast and HPS



## State level correlation between all four

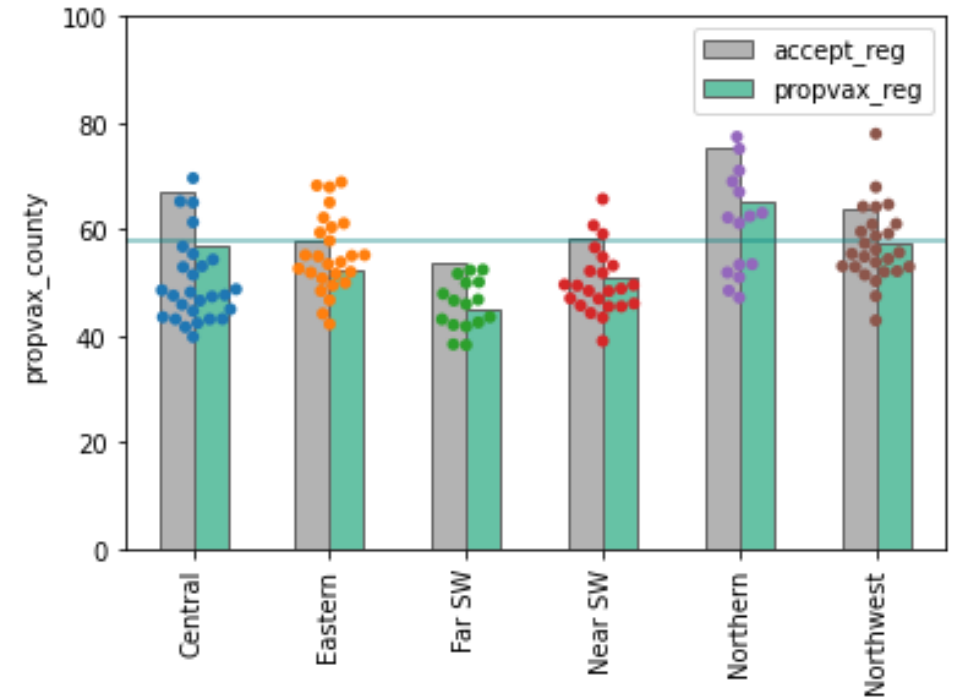


# Vaccination Acceptance by Region

## Corrections to surveys:

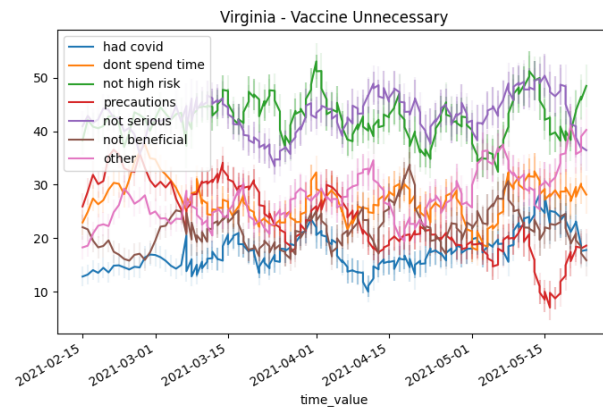
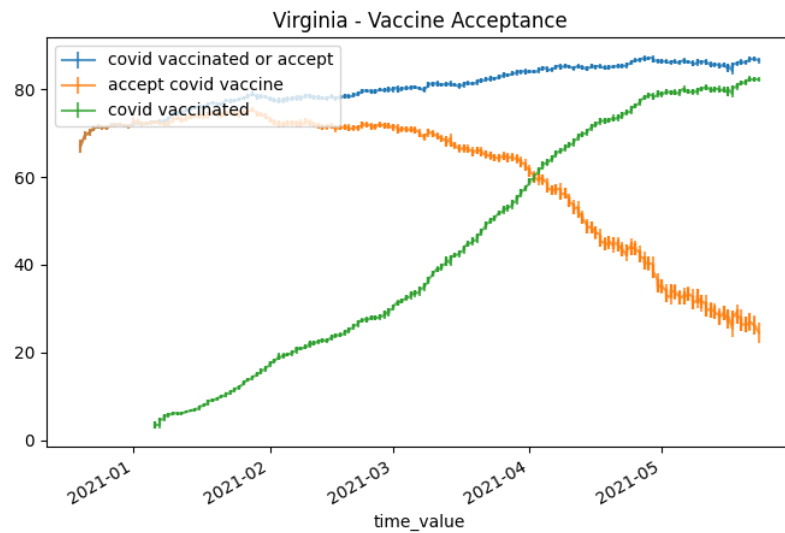
- Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
- Correction approach:
  - Calculate an over-reporting fraction based on reported vaccinations compared to VDH administration data
  - Cross-validate coarse corrections against HPS survey at the state level and corrected in same manner

Region	COVIDcast corrected	COVIDcast uncorrected	VDH proportion vaccinated	COVIDcast reported vaccinated
Central	67%	78%	55%	82%
Eastern	58%	80%	51%	83%
Far SW	54%	70%	43%	74%
Near SW	58%	74%	51%	74%
Northern	75%	85%	65%	88%
Northwest	64%	82%	53%	84%



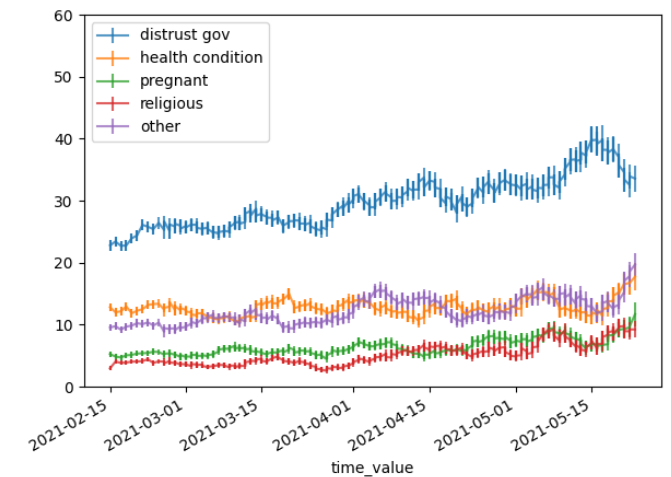
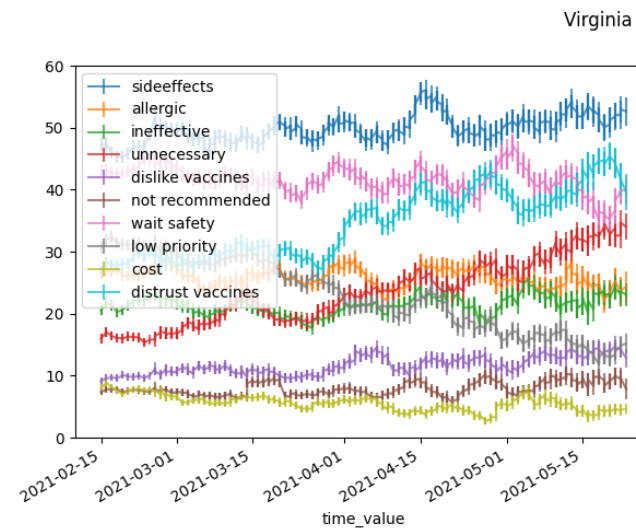
**Grey Bar:** Survey measured and corrected acceptance  
**Green Bar:** Proportion of eligible population administered a vaccine  
**Dots:** Proportion administered at least one dose for each county

# Vaccine Acceptance in Virginia - COVIDcast



## Acceptance remains high:

- Proportion of Virginians that have already or would definitely or probably accept vaccination if offered today
- *Survey respondents are reporting high levels of vaccination of ~80% reflecting bias of the mechanism*
- **Top reasons for hesitancy:** side effects, distrust (increasing), unnecessary (increasing)
- **More likely to take if recommended by:** doctors and friends
- **Reasons unnecessary:** Not serious, not high risk, or other



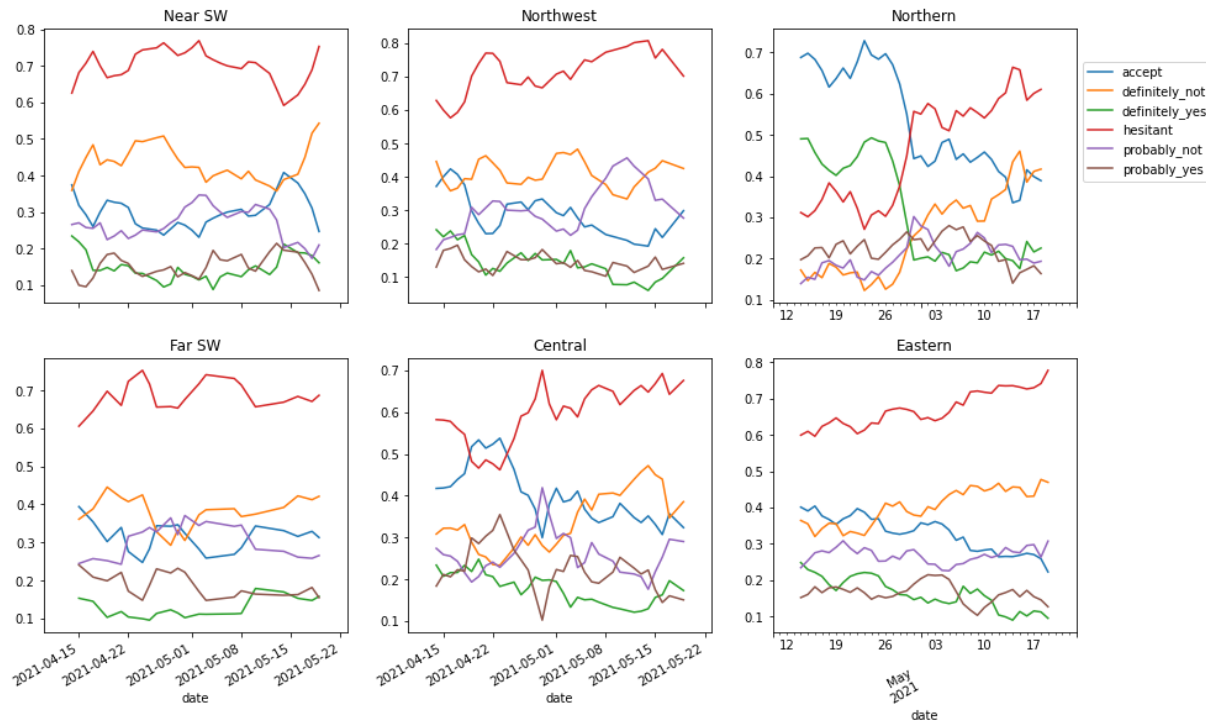
Data Source: <https://covidcast.cmu.edu>

# Vaccine Acceptance by Region- COVIDcast

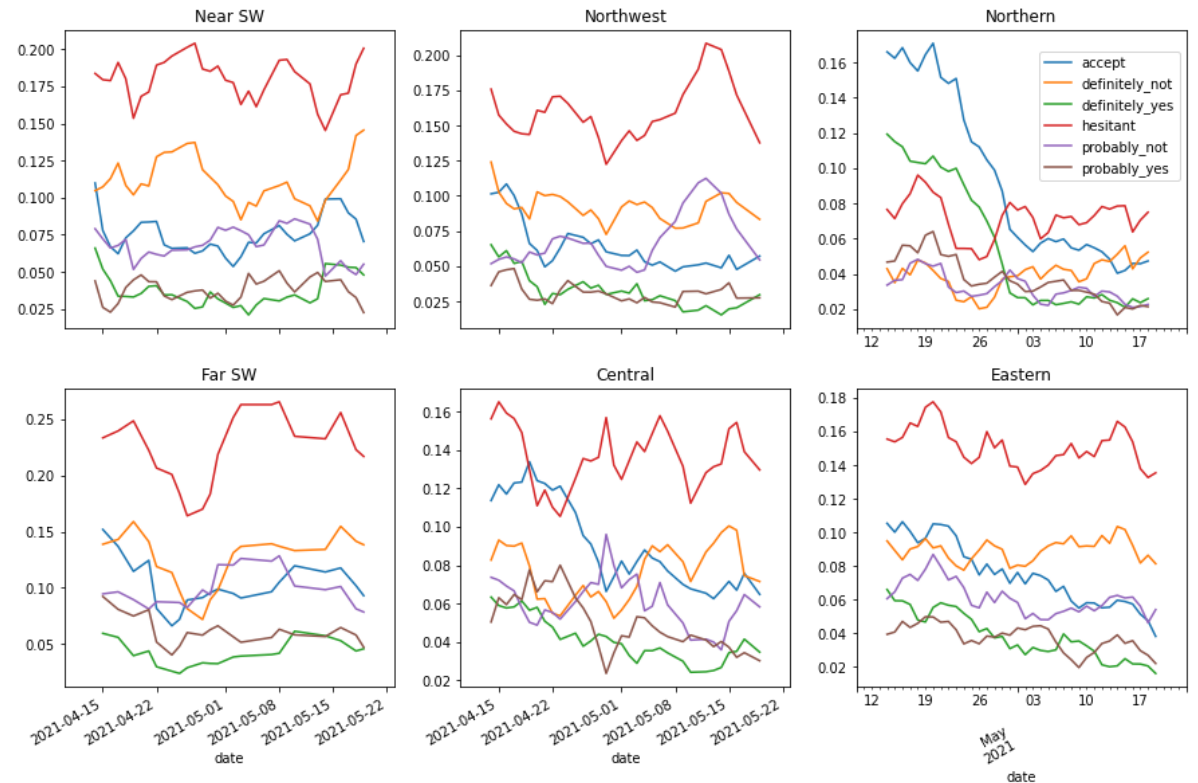
## Levels of Acceptance and potential acceptance in flux:

- Nearly all the “Definitely Yes” have been vaccinated, yet there are 5-10% remaining across the regions
- Northwest and Southwest (to lesser degree) see growth in “probably not”, seemingly from “definitely not”

### Unvaccinated Only



### All Respondents



Data Source: <https://covidcast.cmu.edu>

26-May-21

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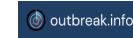
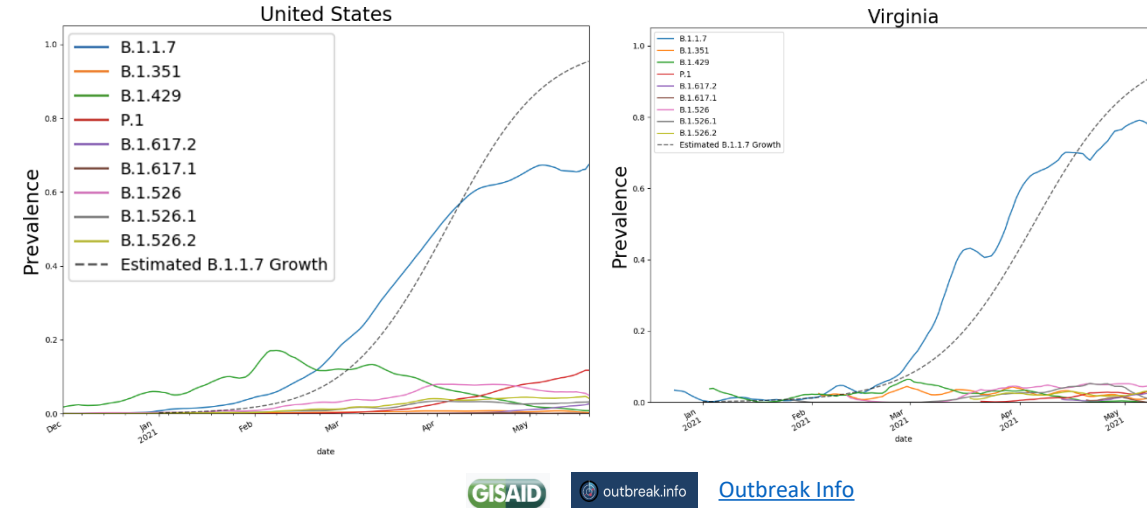
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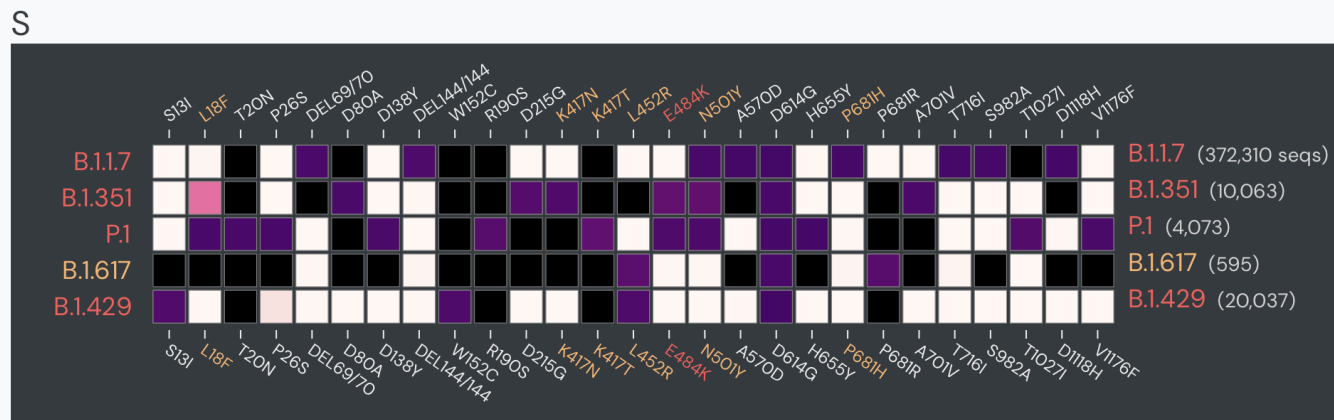
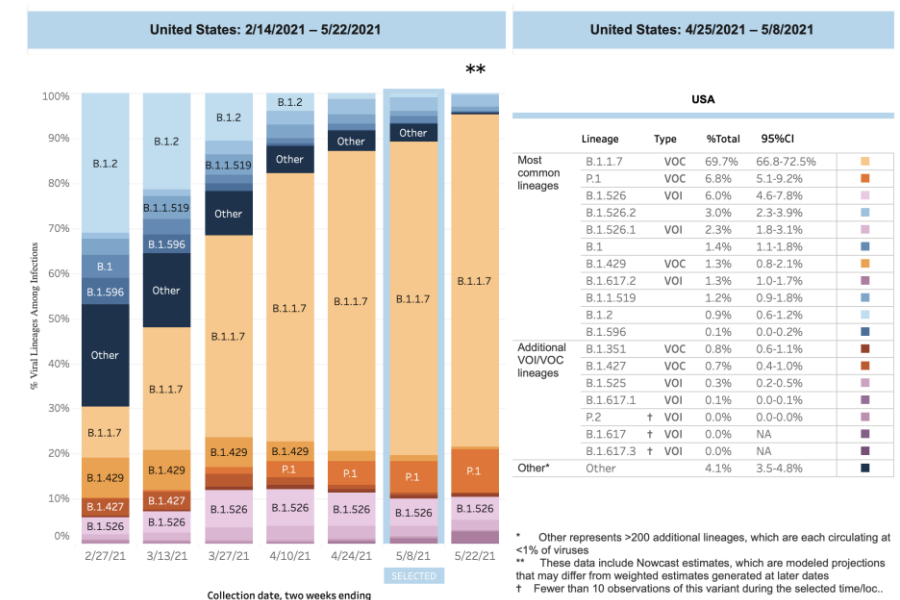
# SARS-CoV2 Variants of Concern

Emerging new variants will alter the future trajectories of pandemic and have implications for future control

- Emerging variants can:
  - Increase transmissibility
  - Increase severity (more hospitalizations and/or deaths)
  - Limit immunity provided by prior infection and vaccinations
- Genomic surveillance remains very limited
  - Challenges ability to estimate impact in US to date and estimation of arrival and potential impact in future



[Outbreak Info](https://www.outbreak.info)



# SARS-CoV2 Variants of Concern

## Lineage B.1.1.7

**Prevalence:** Levels have rapidly risen, as anticipated, and now are plateauing at national level and in many states, seemingly in VA as well

**Transmissibility:** Estimated increase of 50% compared to previous variants. B.1.1.7's mutations aids its infection efficiency, and thus boosts its overall levels of viremia; [study from Public Health England](#) shows contacts of B.1.1.7 cases are more likely (50%) to test positive than contacts of non-B.1.1.7 patients

**Severity:** Increased viremia also appears to increase the risk of hospitalization (60%) and mortality (60%). [Danish](#) study shows B.1.1.7 to have a 64% higher risk of hospitalization, while [Public Health Scotland](#) studies showed a range of 40% to 60%; [Study in Nature](#) based on UK data estimates B.1.1.7 cases have 60% higher mortality

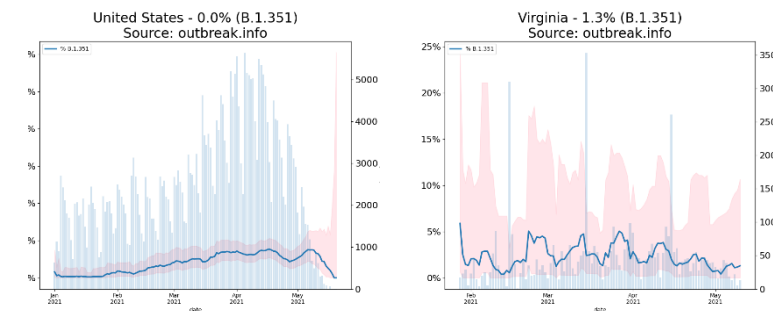
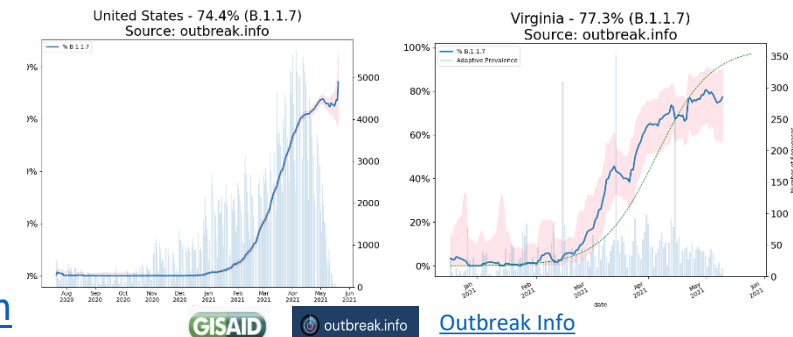
## Lineage B.1.351

**Prevalence:** Levels have remained low, as this variant's transmissibility can't compete with B.1.1.7, however, as more of the population becomes immune it may gain an advantage

**Immune Escape:** Many studies show that convalescent sera from previously infected individuals does not neutralize B.1.351 virus well which is [predictive](#) of [protection](#), however, [vaccine induced immunity](#) shows [signs](#) of [effectiveness](#)

## Lineage [B.1.429/427](#) and [B.1.526](#) and subvariants

- Combined account for around 20% of circulating virus, share may be shrinking as B.1.1.7 outcompetes



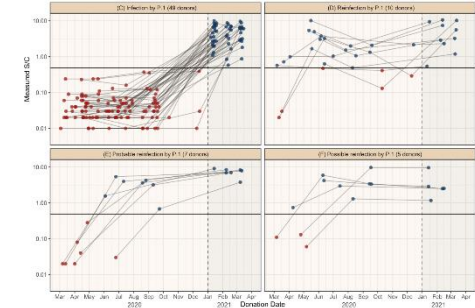
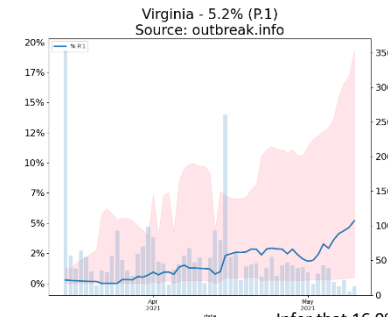
# SARS-CoV2 Variants of Concern

## Lineage P.1

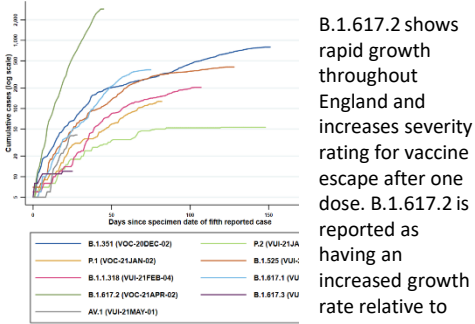
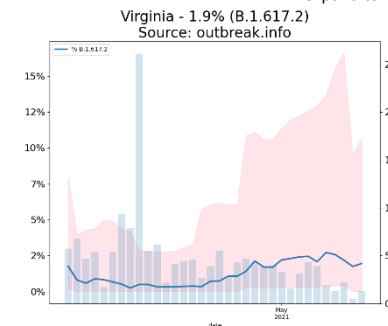
- **Prevalence:** Nationally at 10.7%, lower but increasing in VA at 5.2%
- [New study](#) estimates 17-32% of all infections in Manaus in 2021 were reinfections, which helps explain [data from Brazil](#) demonstrating P.1's continued dominance in Rio despite presence of B.1.1.7

## Lineage B.1.617.2 and related subvariants

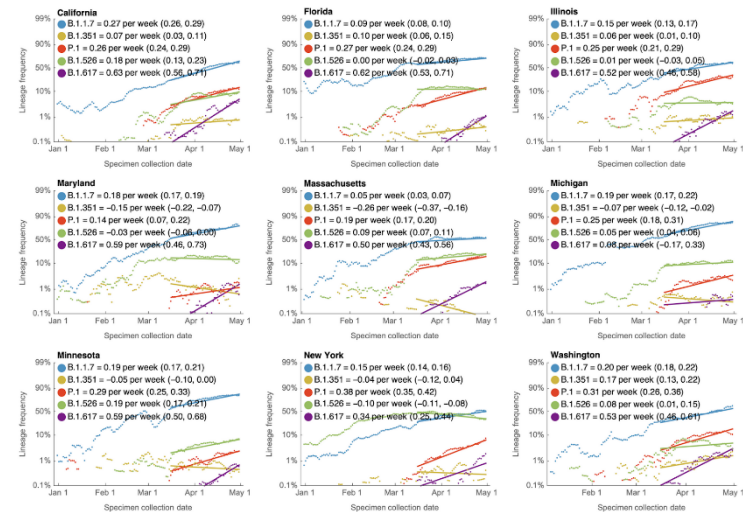
- Continues to drive outbreak in India and neighbors, with immeasurable numbers of cases surpassing healthcare capacities in many regions
- Categorized as [VoC by Public Health England](#), WHO, expect CDC to follow
- Strain shows [continued growth in UK, Europe](#) and in US
- [Several studies](#) estimate B.1.617.2 to have 100% faster growth than B.1.1.7, and UK study suggests a 13% advantage over B.1.1.7
- [More studies](#) show limited [immune escape](#) similar to B.1.351, however, still suggest protection remains for vaccinated
- [PHE study](#) shows limited efficacy of Astra-Zeneca with only one dose, efficacy returns following 2<sup>nd</sup> dose



Infer that 16.9% (95% CI [9.48%, 28.5%]) of all presumed P.1 infections that were observed in 2021 were reinfections. Including probable or possible reinfections this expand to 25.8% (95% CI [16.7%, 37.4%]), and 31.0% (95% CI [21.4%, 42.5%]). [medRxiv](#)



B.1.617.2 shows rapid growth throughout England and increases severity rating for vaccine escape after one dose. B.1.617.2 is reported as having an increased growth rate relative to B.1.1.7. PHE [report 1](#) and [report 2](#)

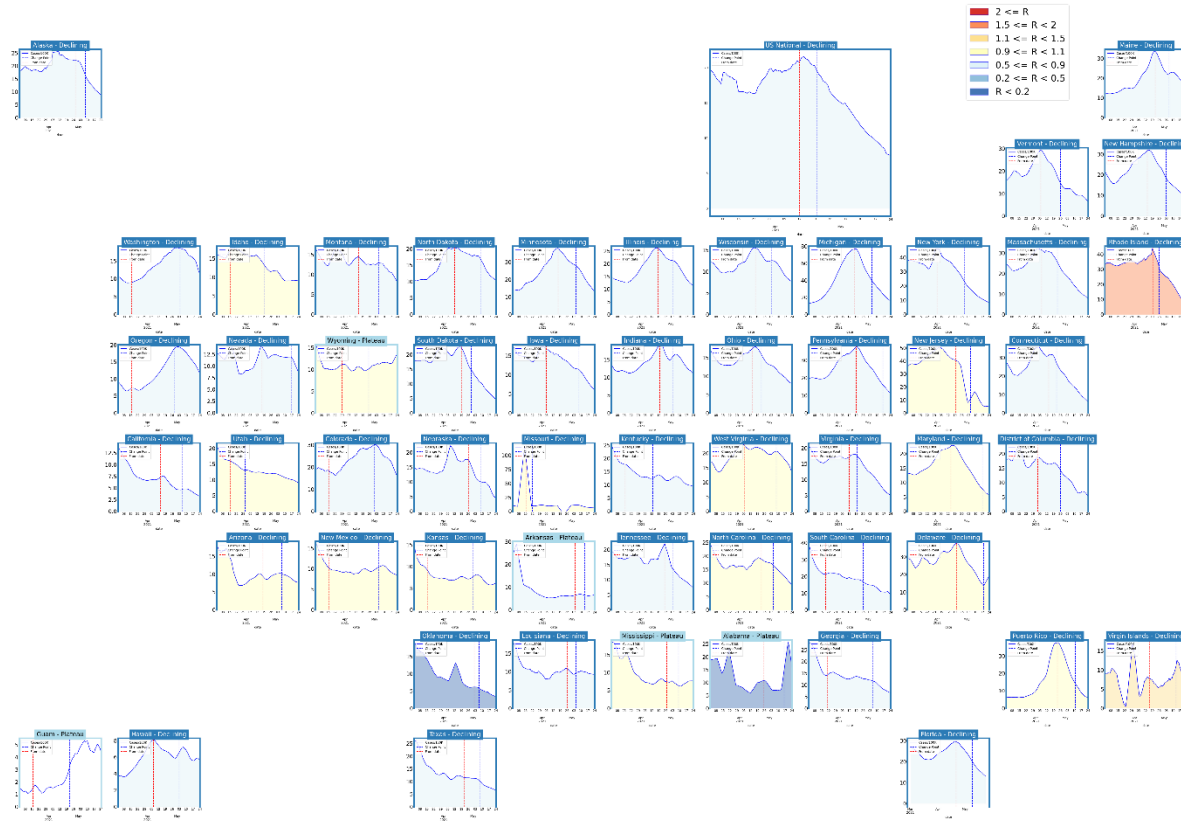


Growth in US continues in the 0.5-0.6 growth rate range, eclipsing most other strains, remains at low levels, but is growing [Nextstrain analysis](#)



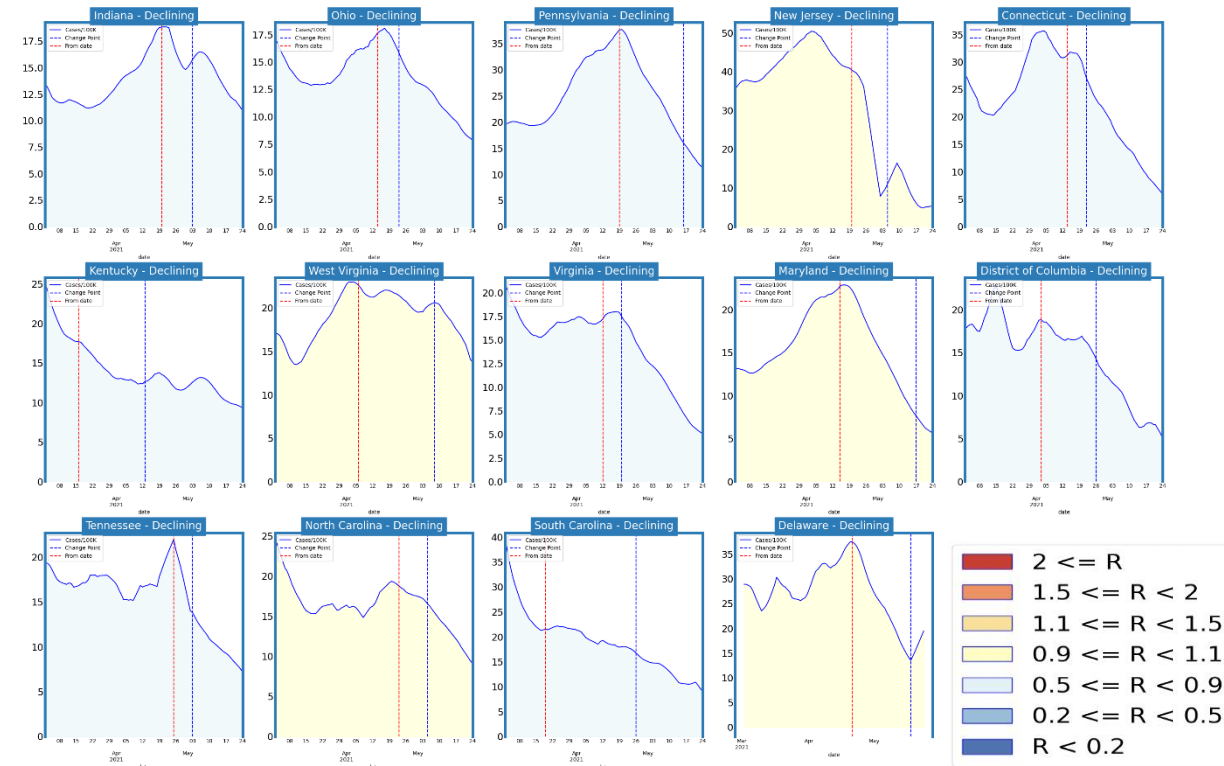
# Other State Comparisons

## Trajectories of States



- Nearly all states are declining
- Growth out west has slowed, recent reporting artifacts in some states perturb the otherwise calm picture

## Virginia and her neighbors

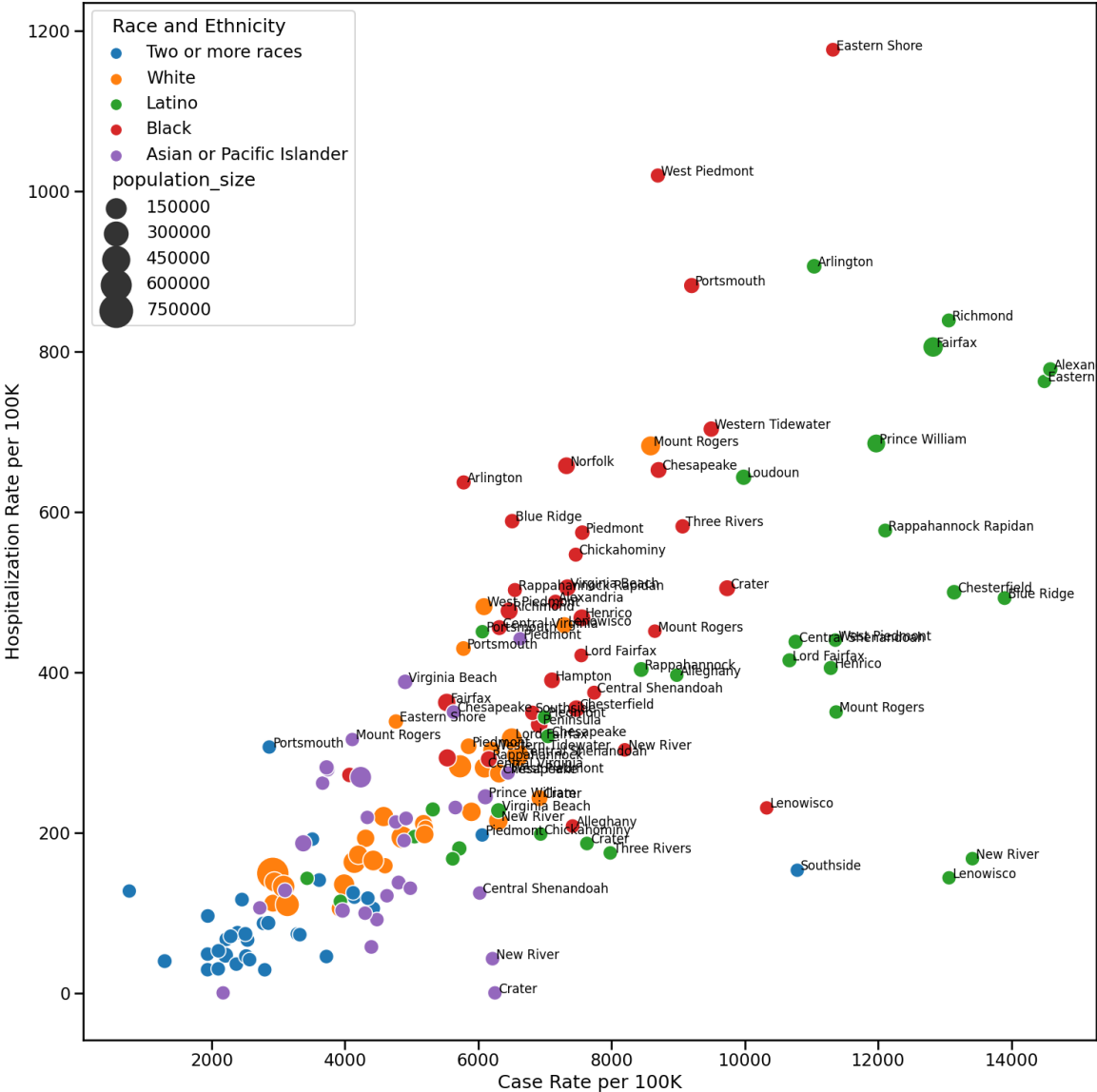


- VA and neighbors are all declining with steady pace
- Most neighbors are now below 10/100K level

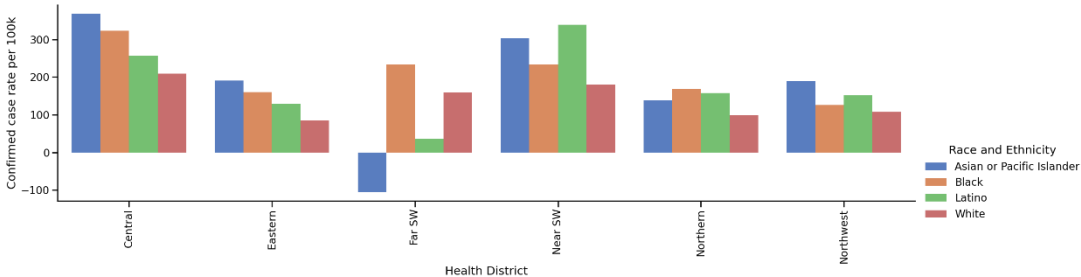
# Race and Ethnicity cases per 100K

## Rates per 100K of each Racial-Ethnic population by Health District

- Each Health District's Racial-Ethnic population is plotted by their Hospitalization and Case Rate
- Points are sized based on their overall population size (overlapping labels removed)
- Change in rates over the last 2 weeks



## Case Rate Change in last 14 days

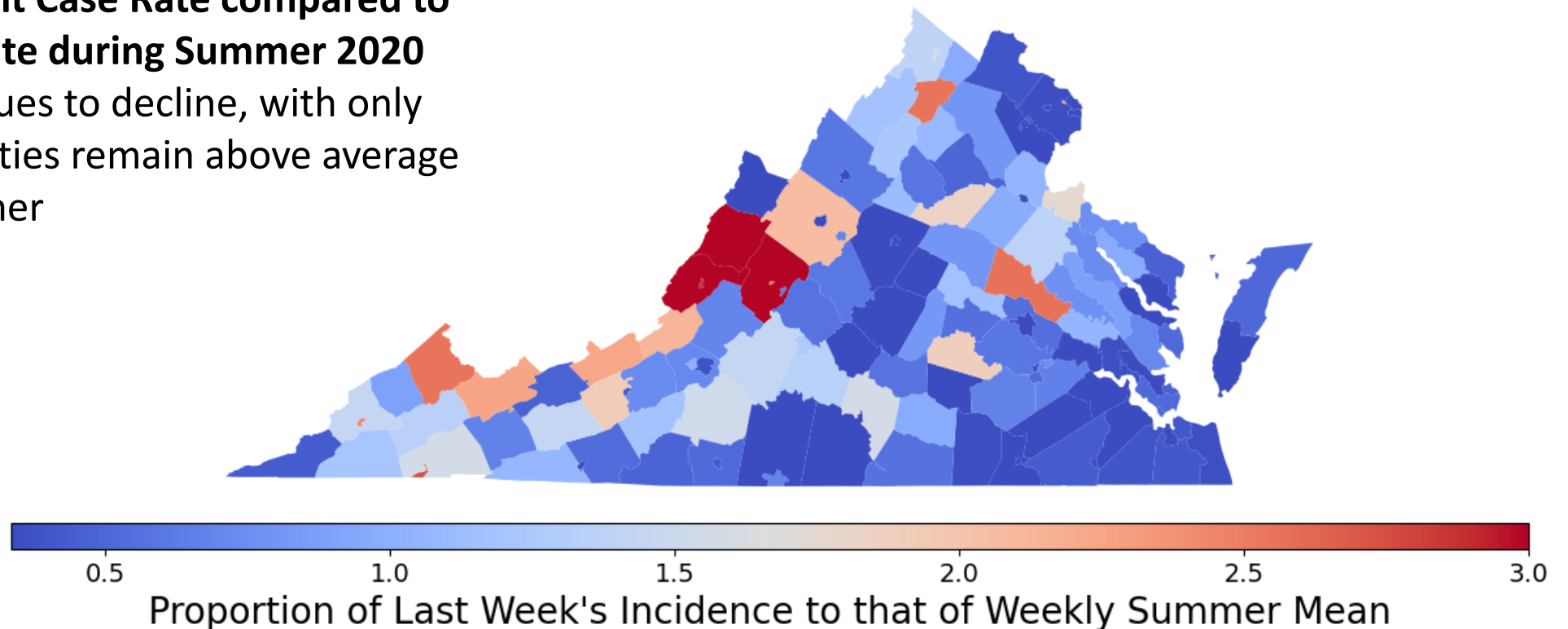


# Recent Incidence Compared to Summer 2020

Recent Incidence Compared to Weekly Summer Mean by County  
Mean: 0.92; Median: 0.6; IQR: 0.34-1.18

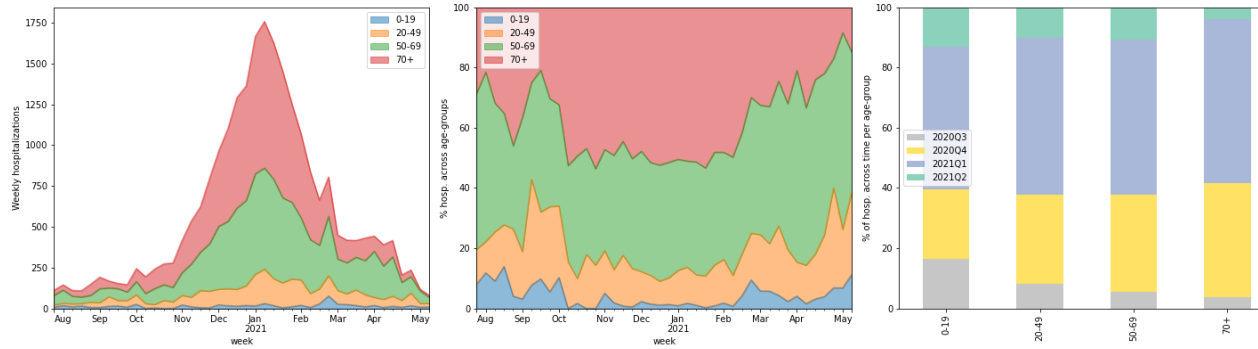
## Ratio of Recent Case Rate compared to mean Case Rate during Summer 2020

- Ratio continues to decline, with only 32% of counties remain above average of last summer

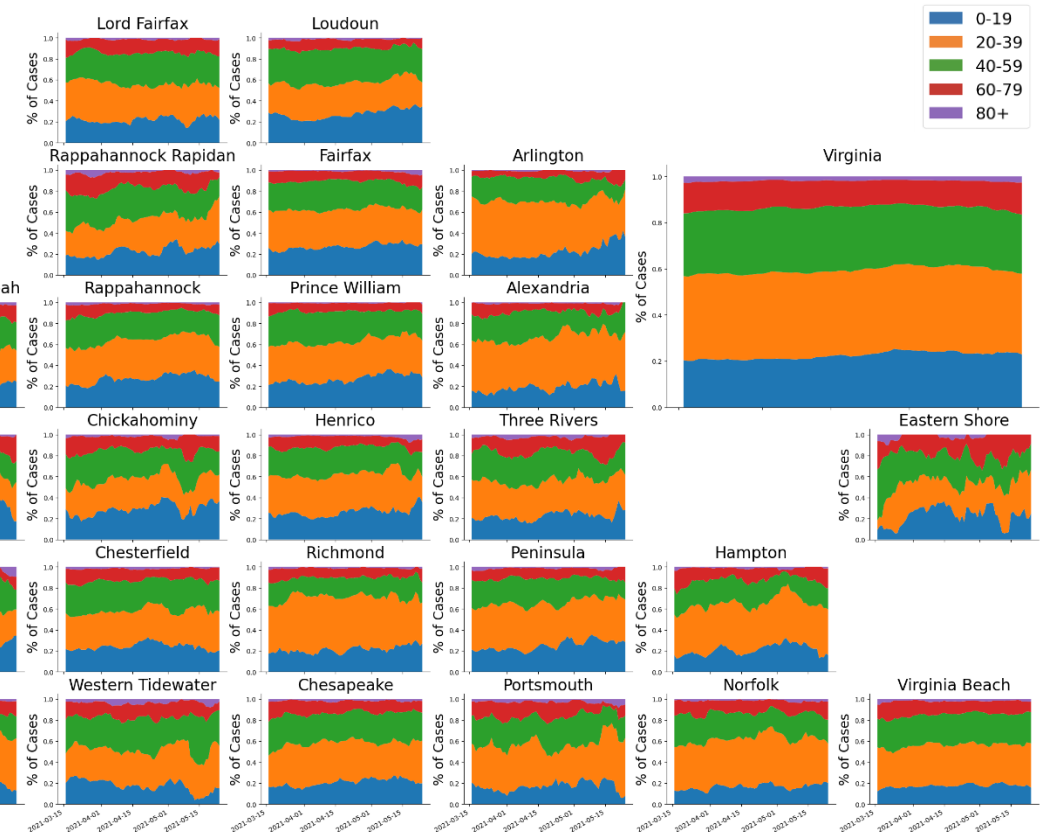


# Shifting Age-Distributions

## Hospitalizations in VA



## Cases in VA



- Hospitalizations shifting younger to middle age
- Cases after shifting younger are returning to 60-79 as prevalence is low and hesitancy hits in these groups

# Zip code level weekly Case Rate (per 100K)

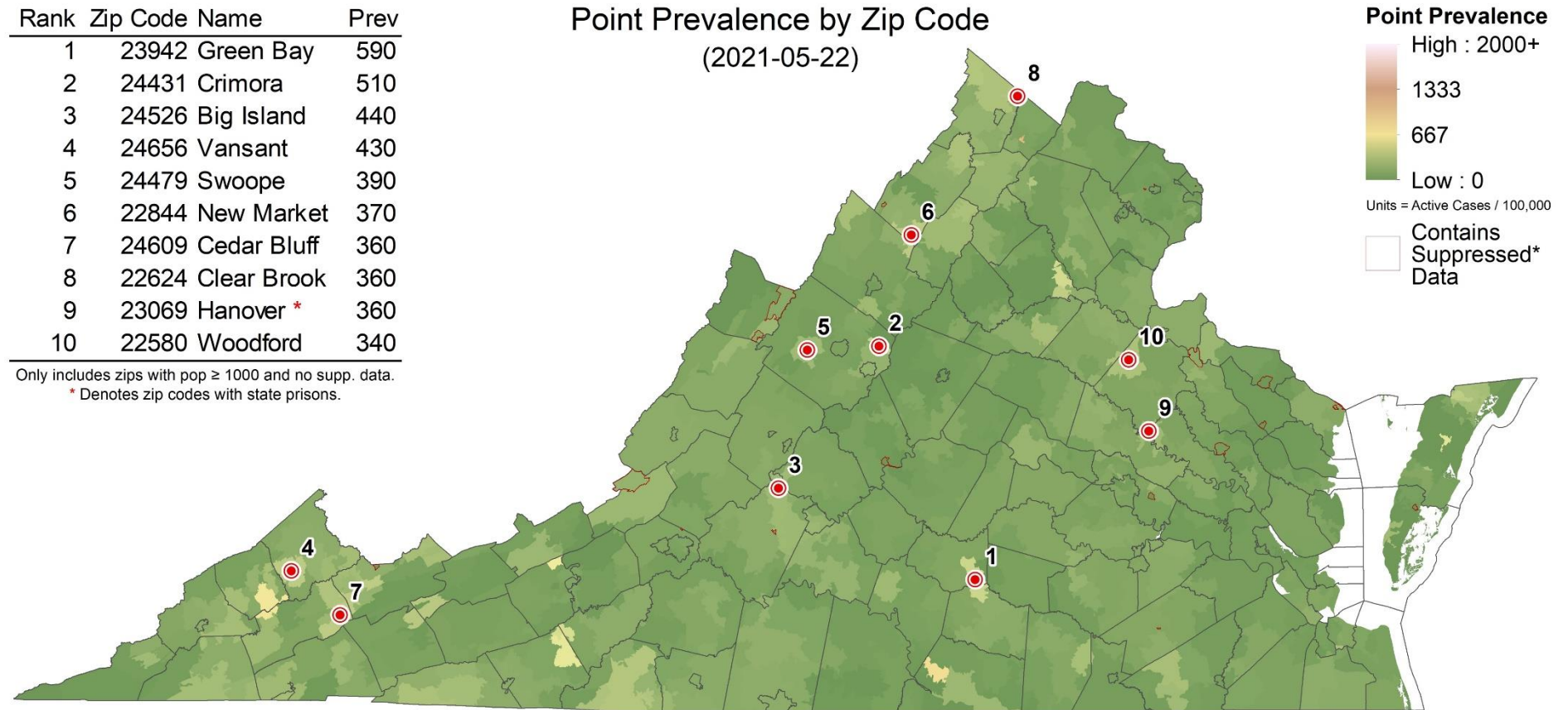
## Case Rates in the last week by zip code

- Concentrations in Southwest, which was preceded by cluster of increased HCW rates last week
- Still some universities in top 10
- Some counts are low and suppressed to protect anonymity, those are shown in white

Rank	Zip Code	Name	Prev
1	23942	Green Bay	590
2	24431	Crimora	510
3	24526	Big Island	440
4	24656	Vansant	430
5	24479	Swoope	390
6	22844	New Market	370
7	24609	Cedar Bluff	360
8	22624	Clear Brook	360
9	23069	Hanover *	360
10	22580	Woodford	340

Only includes zips with pop ≥ 1000 and no supp. data.

\* Denotes zip codes with state prisons.



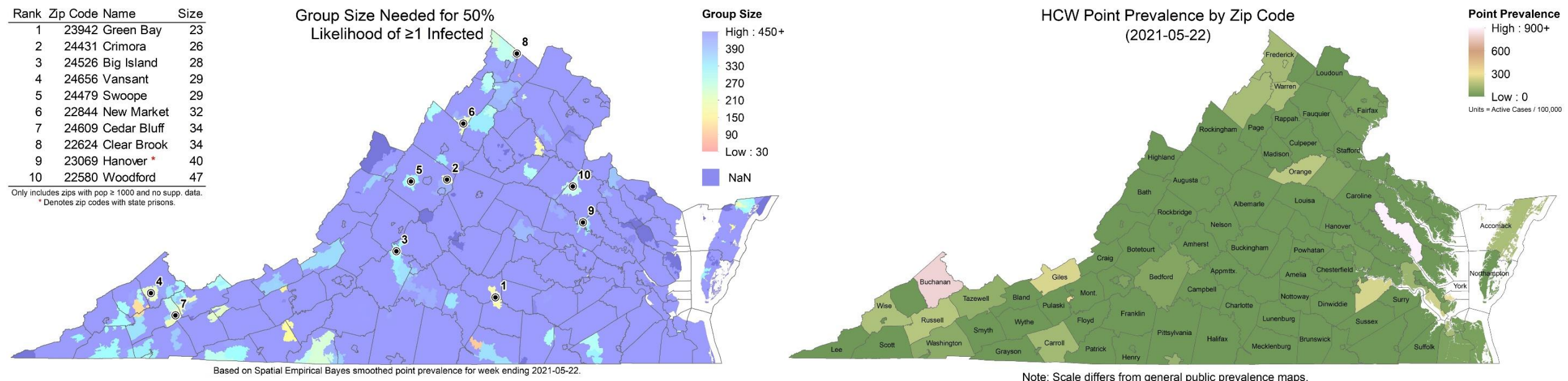
Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-05-22.



# Risk of Exposure by Group Size and HCW prevalence

## Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25)

- **Group Size:** Assumes 2 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey), and shows minimum size of a group with a 50% chance an individual is infected by zip code (eg in a group of 23 in Green Bay, there is a 50% chance someone will be infected)
- **HCW prevalence:** Case rate among health care workers (HCW) in the last week using patient facing health care workers as the denominator

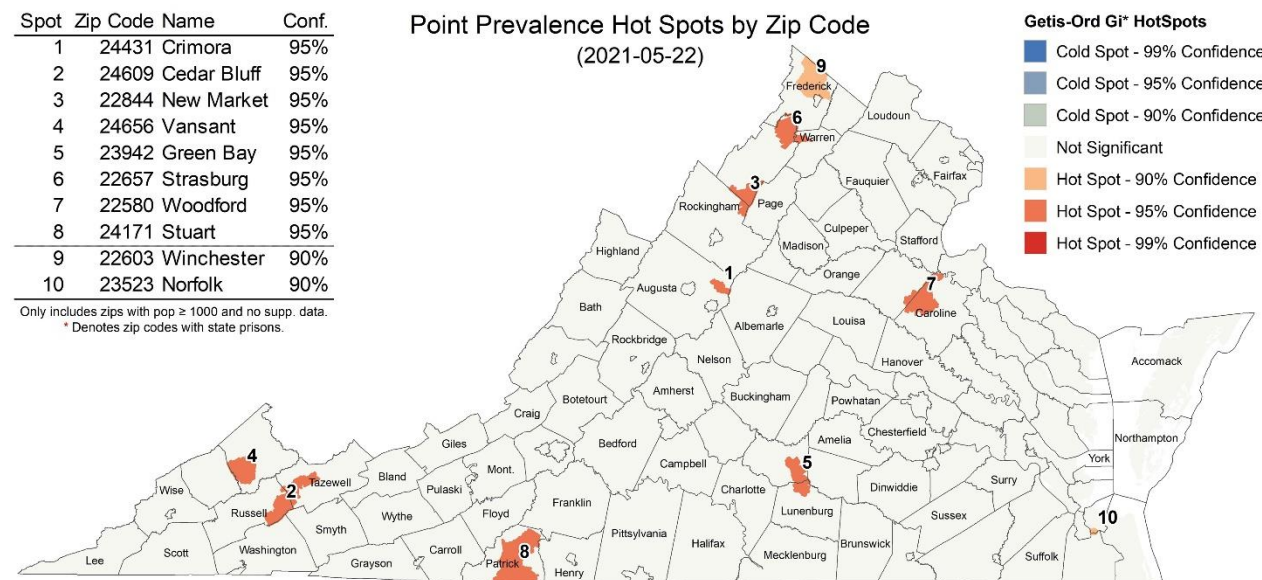


# Current Hot-Spots

## Case rates that are significantly different from neighboring areas or model projections

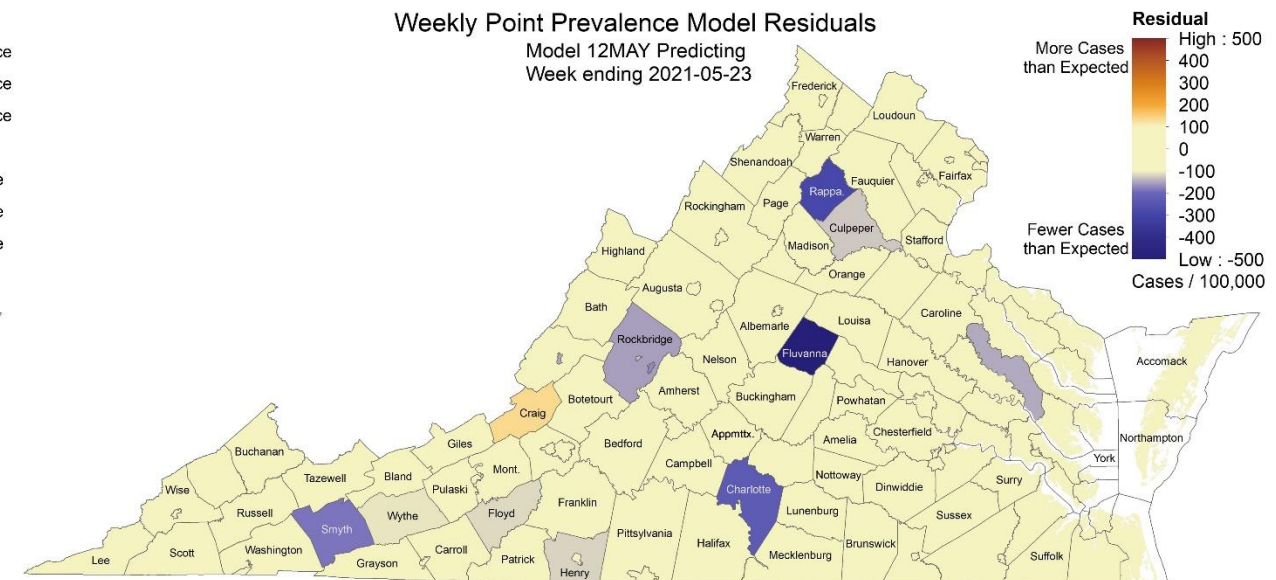
- **Spatial:** SaTScan based hot spots compare clusters of zip codes with weekly case prevalence higher than nearby zip codes to identify larger areas with statistically significant deviations
- **Temporal:** The weekly case rate (per 100K) projected last week compared to observed by county, which highlights temporal fluctuations that differ from the model's projections

### Spatial Hotspots



Based on Global Empirical Bayes smoothed point prevalence for week ending 2021-05-22.

### Temporal Hotspots



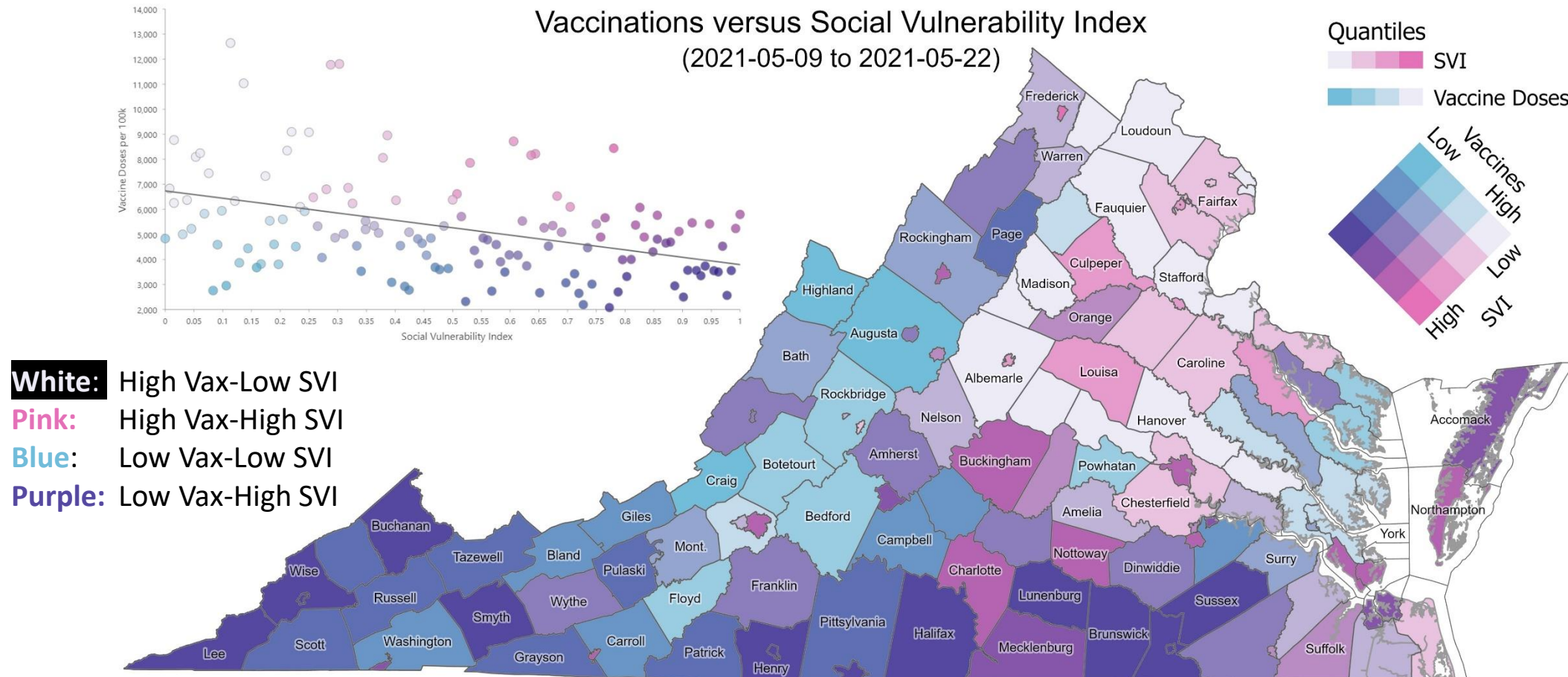
Moran's I = 0.012974, Z-Score = 0.283992, P-Value = 0.776417  
No Residual Autocorrelation Detected



# Social Vulnerability and Recent Vaccination Rates

## Comparison of social vulnerability and vaccination rate in last 2 weeks by county

- **Social Vulnerability:** Each county's Social Vulnerability Index (CDC) compared with the level of vaccination

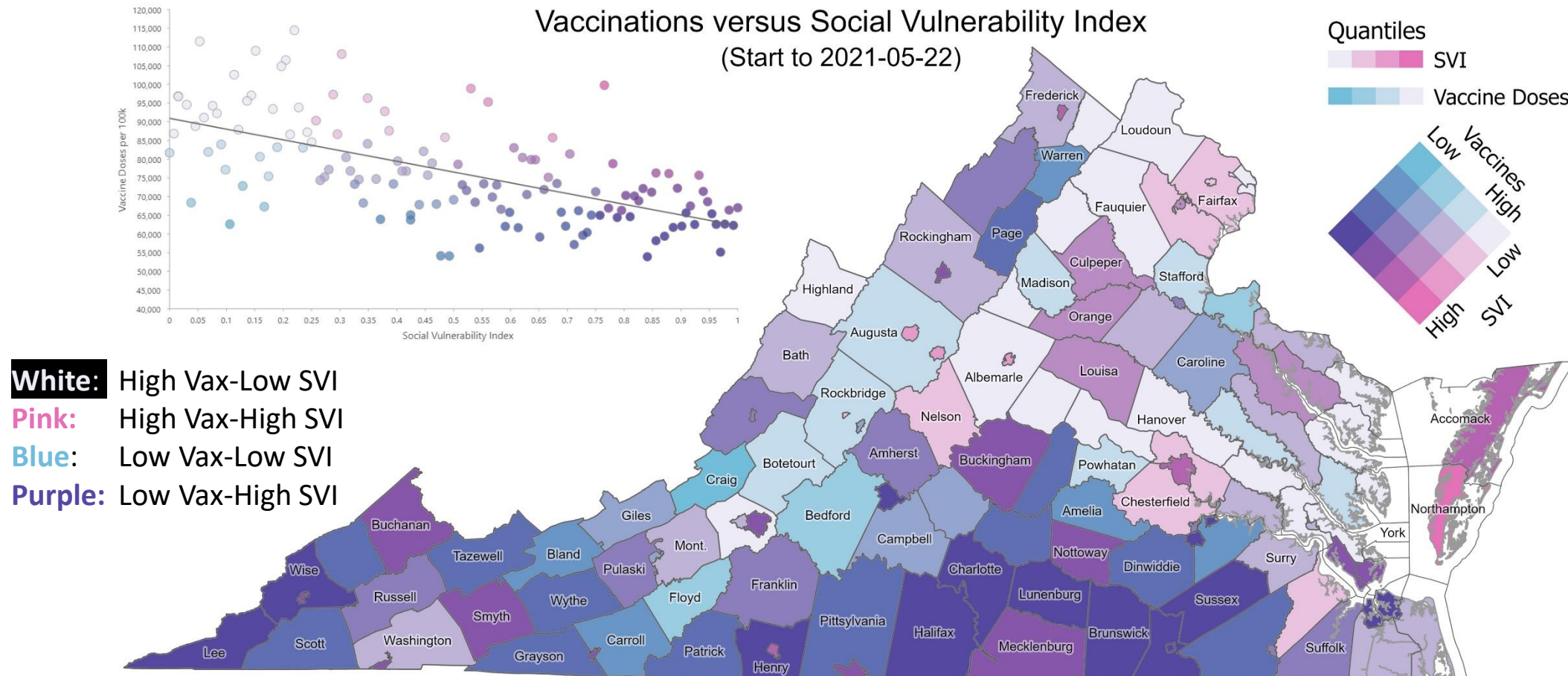




# Social Vulnerability and Total Vaccination Rates

## Comparison of social vulnerability and total vaccination rate since the start of vaccination

- **Social Vulnerability:** Each county's Social Vulnerability Index (CDC) compared with the level of vaccination



# Model Update – Adaptive Fitting

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# Adaptive Fitting Approach

## Each county fit precisely, with recent trends used for future projection

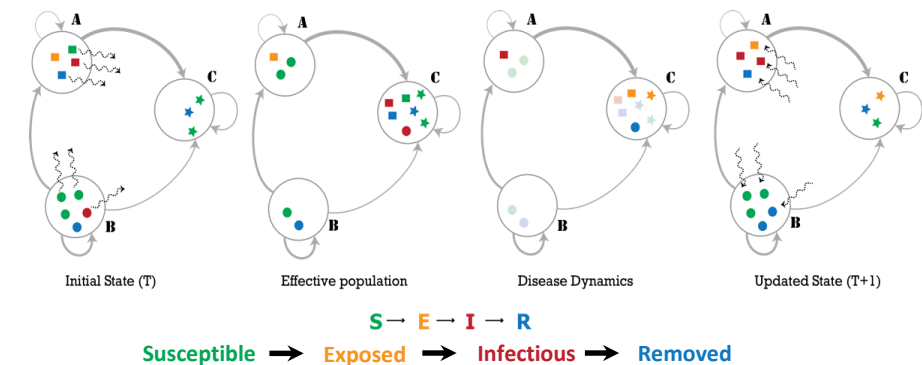
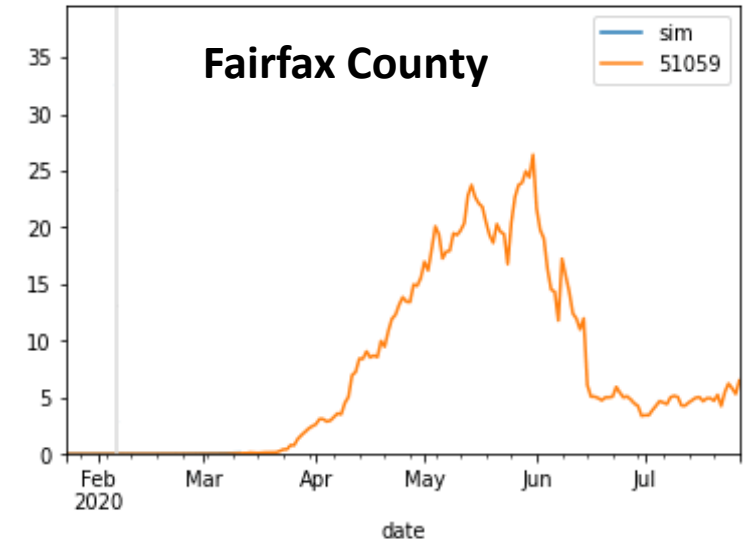
- Allows history to be precisely captured, and used to guide bounds on projections

## Model: An alternative use of the same meta-population model, PatchSim

- Allows for future “what-if” Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

## External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions
- Uses steady 1 case per 10M population per day external seeding



# Using Ensemble Model to Guide Projections

Ensemble methodology that combines the Adaptive with machine learning and statistical models such as:

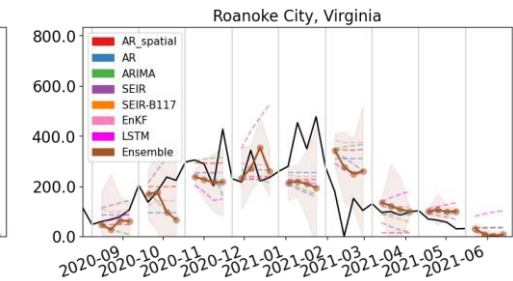
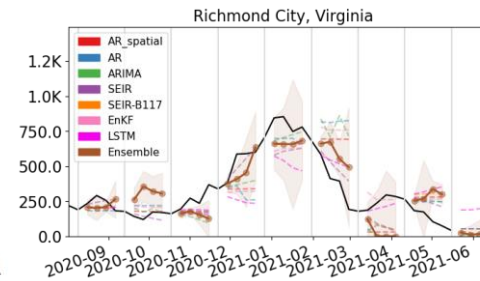
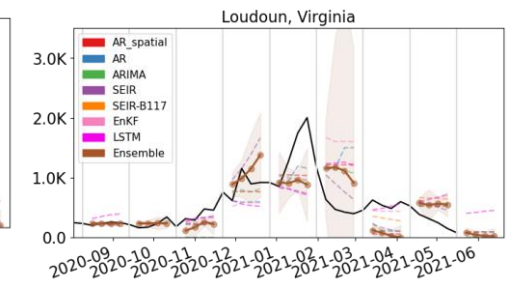
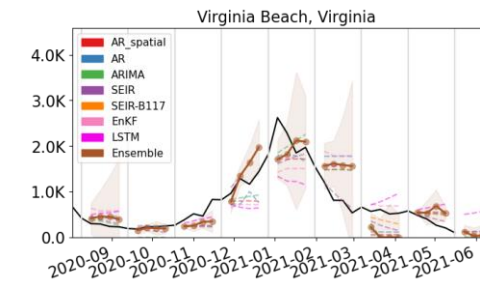
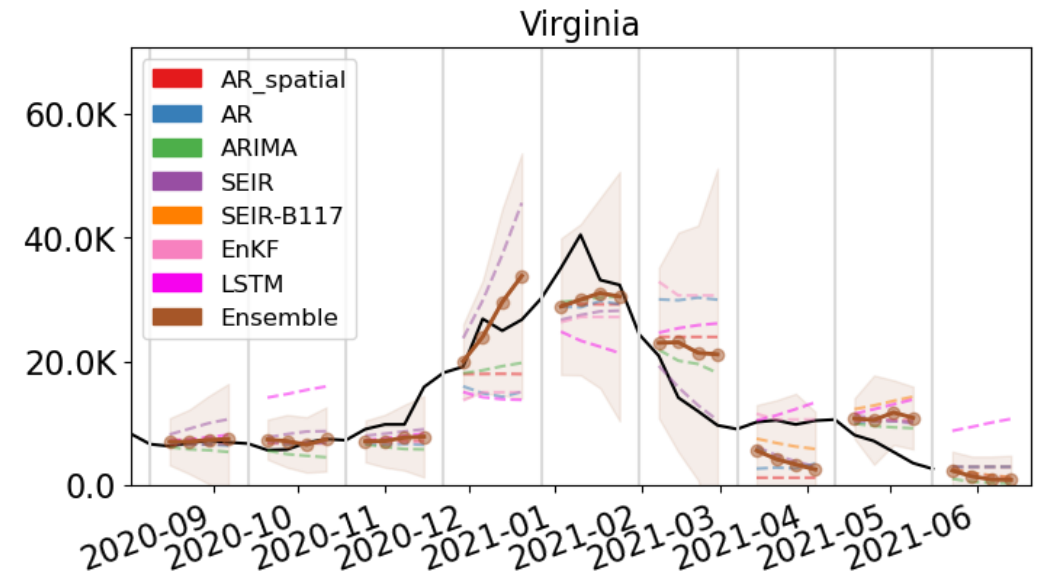
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

Weekly forecasts done at county level.

Models chosen because of their track record in disease forecasting and to increase diversity and robustness.

Ensemble forecast provides additional 'surveillance' for making scenario-based projections.

Also submitted to CDC Forecast Hub.



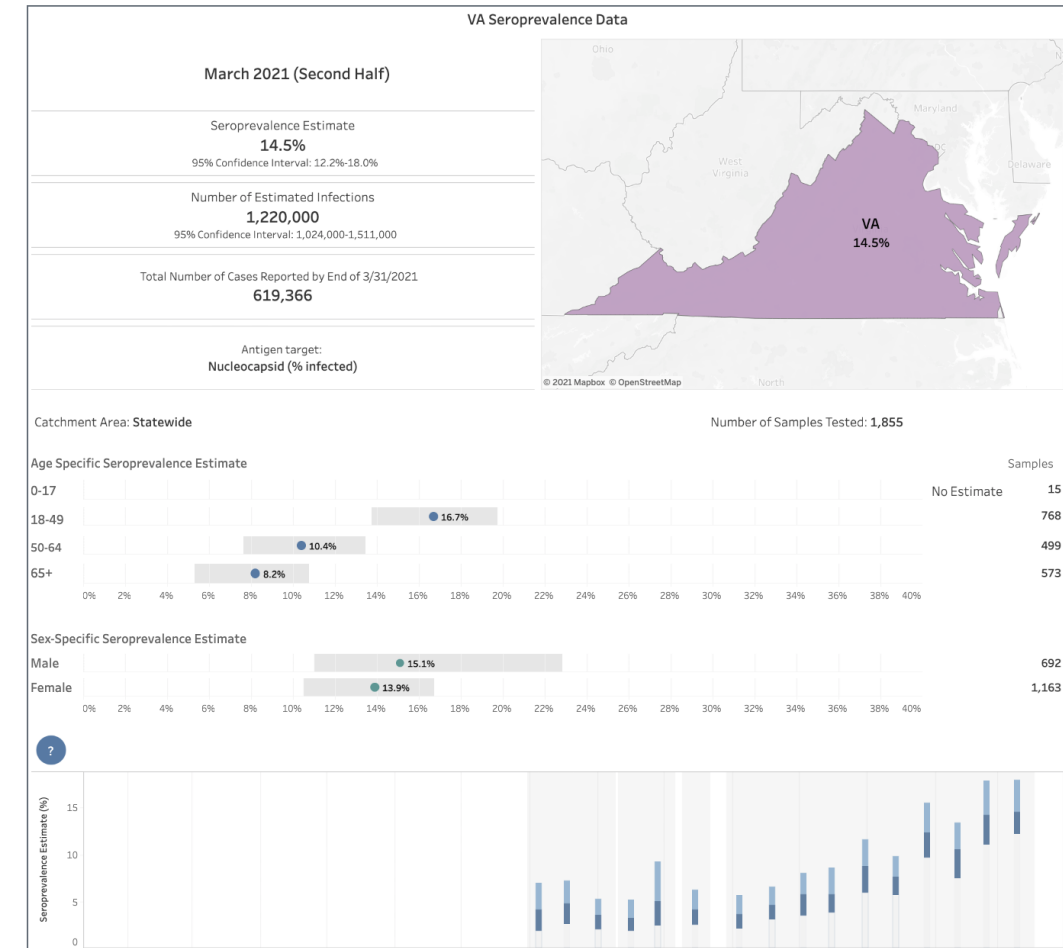
# Seroprevalence updates to model design

**Several seroprevalence studies provide better picture of how many actual infections have occurred**

- CDC Nationwide Commercial Laboratory Seroprevalence Survey estimated 14.5% [12% – 18%] seroprevalence as of March 4<sup>th</sup> – 17<sup>th</sup> up from 10.5% a month earlier

**These findings are equivalent to an ascertainment ratio of ~2x in the future, with bounds of (1.3x to 3x)**

- Thus for 2x there are 2 total infections in the population for every confirmed case recently
- This measure now fully tracks the estimated ascertainment over time
- Uncertainty design has been shifted to these bounds (previously higher ascertainments as was consistent earlier in the pandemic were being used)



<https://covid.cdc.gov/covid-data-tracker/#national-lab>



# Calibration Approach

- **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting
- **Calibration:** fit model to observed data and ensemble's forecast
  - Tune transmissibility across ranges of:
    - Duration of incubation (5-9 days), infectiousness (3-7 days)
    - Undocumented case rate (1x to 7x) guided by seroprevalence studies
    - Detection delay: exposure to confirmation (4-12 days)
  - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak
- **Project:** future cases and outcomes generated using the collection of fit models run into the future
  - **Mean trend from last 7 days of observed cases and first week of ensemble's forecast used**
  - Outliers removed based on variances in the previous 3 weeks
  - 2 week interpolation to smooth transitions in rapidly changing trajectories

## COVID-19 in Virginia:

Dashboard Updated: 5/18/2021  
Data entered by 5:00 PM the prior day.

Cases, Hospitalizations and Deaths					
Total Cases*		Total Hospitalizations**		Total Deaths	
<b>670,834</b>		<b>29,290</b>		<b>11,042</b>	
(New Cases: 378)^					
Confirmed†	Probable†	Confirmed†	Probable†	Confirmed†	Probable†
522,362	148,472	27,802	1,488	9,319	1,723

\* Includes both people with a positive test (Confirmed), and symptomatic with a known exposure to COVID-19 (Probable).  
 \*\* Hospitalization of a case is captured at the time VDH performs case investigation. This underrepresents the total number of hospitalizations in Virginia.  
 ^New cases represent the number of confirmed and probable cases reported to VDH in the past 24 hours.  
 † VDH adopted the updated CDC COVID-19 confirmed and probable surveillance case definitions on August 27, 2020. Found here: <https://www.cdc.gov/nndss/conditions/coronavirus-disease-2019-covid-19/case-definition/2020/08/05/>

Outbreaks	
Total Outbreaks*	Outbreak Associated Cases
<b>3,519</b>	<b>75,664</b>

\* At least two (2) lab confirmed cases are required to classify an outbreak.

Testing (PCR Only)	
Testing Encounters PCR Only*	Current 7-Day Positivity Rate PCR Only**
<b>7,285,852</b>	<b>3.2 %</b>

\* PCR refers to "Reverse transcriptase polymerase chain reaction laboratory testing."  
 \*\* Lab reports may not have been received yet. Percent positivity is not calculated for days with incomplete data.

Multisystem Inflammatory Syndrome in Children	
Total Cases*	Total Deaths
<b>70</b>	<b>0</b>

\*Cases defined by CDC HAN case definition: <https://emergency.cdc.gov/han/2020/han00432.asp>

Accessed 9:00am May 26, 2021

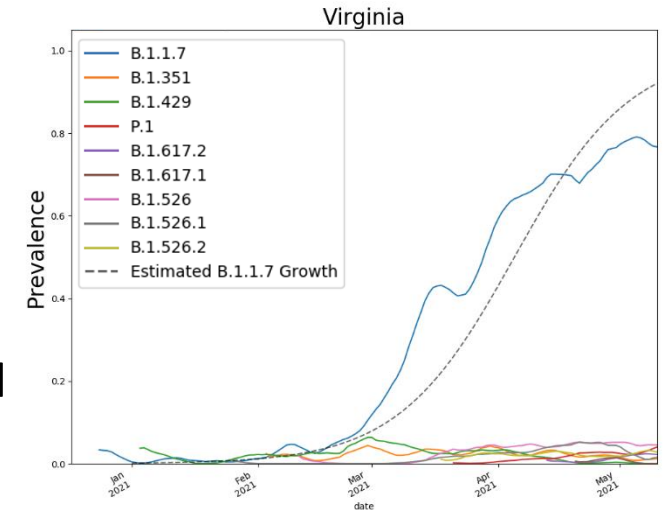
<https://www.vdh.virginia.gov/coronavirus/>

# Scenarios – Transmission Conditions

- Variety of factors continue to drive transmission rates
  - Seasonal impact of weather patterns, travel and gatherings, fatigue and premature relaxation of infection control practices
- Plausible levels of transmission can be bounded by past experience
  - Assess transmission levels at the county level from May 1, 2020 – Sept 1, 2020 or current, whichever is highest
- Projection Scenario:
  - **Adaptive:** Control remains as is currently experienced into the future
  - **Fatigued Control:**
    - Highest level of transmission (95<sup>th</sup> percentile) increased by additional 5%
    - Transition to this level over 4 weeks, remain at this level for the summer, then return to Adaptive
- Additional study scenarios with Fall Resurgence:
  - **Fall:** Resurgence to worst of Fall 2020 starting in September and ramping up quickly

# Scenarios – Mixed Variants Condition

- Variant B.1.1.7 has reached dominance in Virginia but no longer is growing at a predictable pace as variants compete
- Other variants with differing levels of transmissibility, immune escape, and impacts on severity also exist, to varying degrees
- Transmissibility boosting effects and growth of variants are no longer predictable
  - Rely on adaptive fitting to find transmissibility trends for projection
- Immune Escape
  - Many variants demonstrate the ability to evade immunity, both natural and vaccine-induced, uncertainty remains high thus this is not factored into the model
- Impact on Severity
  - Assume current variant prevalence remain relatively stable into future
  - Severity increases:
    - B.1.1.7 = 1.6 times hospitalization and death
    - P.1 = 1.5 times hospitalization and death
    - B.1.351 = 1.5 times hospitalization and death





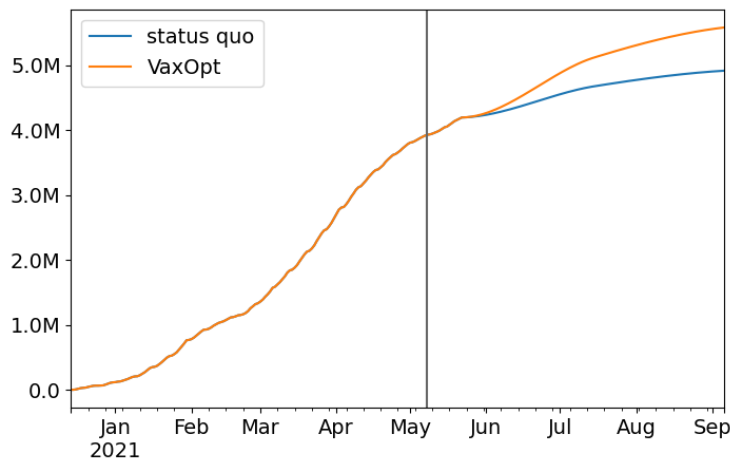
# Scenarios – Vaccination Conditions

## Assumed vaccine efficacies

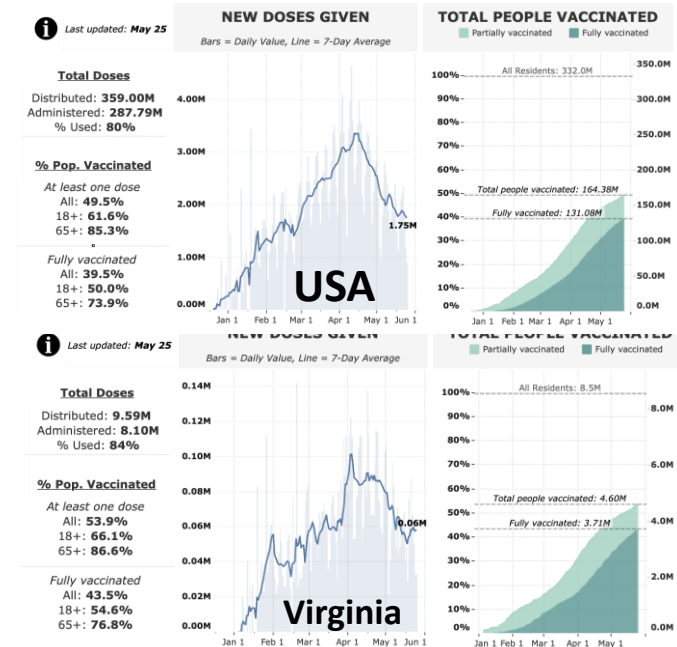
- **Pfizer/Moderna:** 50% after first dose, 95% after second dose (3.5 week gap)
- **J & J :** 67% efficacy after first (and only) dose
- Delay to efficacy from doses is 14 days, immunity lasts at least 7m ([NEJM study](#))

## Two Vaccine Administration Scenarios

- Acceptance at county level = regional acceptance +/- relative current vax
- **Status quo (no label):** COVIDcast corrected acceptance estimate [VA ~65%] by Labor Day. County level heterogeneity based on cumulative uptake
- **Optimistic (VaxOpt):** Expand VA acceptance to 75% (~13% higher per county).
- Front-loaded rollout (two-thirds of the remaining in half the time)

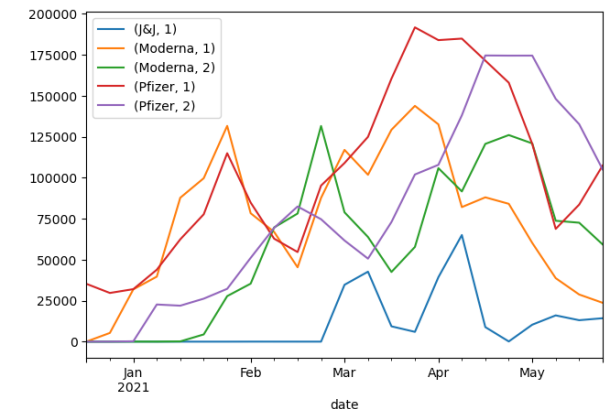


	status quo		VaxOpt	
	Date		Date	
Monthly first doses	2020-12-31	114.3K	114.3K	
	2021-01-31	653.7K	653.7K	
	2021-02-28	564.2K	564.2K	
	2021-03-31	1.3M	1.3M	
	2021-04-30	1.1M	1.1M	
	2021-05-31	445.0K	467.7K	
	2021-06-30	311.7K	604.0K	
	2021-07-31	226.7K	440.6K	
	2021-08-31	132.6K	255.2K	
	2021-09-30	15.7K	30.1K	
Cumulative	2020-12-31	114.3K	114.3K	
	2021-01-31	768.0K	768.0K	
	2021-02-28	1.3M	1.3M	
	2021-03-31	2.6M	2.6M	
	2021-04-30	3.8M	3.8M	
	2021-05-31	4.2M	4.3M	
	2021-06-30	4.5M	4.9M	
	2021-07-31	4.8M	5.3M	
	2021-08-31	4.9M	5.6M	
	2021-09-30	4.9M	5.6M	



Source: [https://ckelly17.github.io/vaccine\\_dashboard.html](https://ckelly17.github.io/vaccine_dashboard.html)

## Weekly VA doses administered by manufacturer



# Scenarios – Combined Conditions

Name	Txm Controls	Variant Boosting	Vax	Description
Adaptive	C	Mixed	SQ	Likely trajectory based on conditions remaining similar to how they are now
Adaptive-FatigueControl	F	Mixed	SQ	Worst case trajectory if control conditions deteriorate to highest transmission rates of the past
Adaptive-VaxOpt	C	Mixed	VO	Likely trajectory based on conditions remaining similar to now, but with improvements to vaccine acceptance
Adaptive-FatigueControl-VaxOpt	F	Mixed	VO	Worst case trajectory if control conditions deteriorate to worst of the past, with improvements to vax acceptance

**Transmission Controls:** C = Current levels persist into the future

F = Fatiguing controls drift to worst levels of last summer and persist

**Variant Boosting:**

Mixed = Variety of variants, no future txm boosting, but with severity impacts from current levels

**Vaccinations:**

SQ = Status quo acceptance leads to low rates of vaccination through the summer

VO = Vaccination acceptance optimistically expands with increased rates through the summer

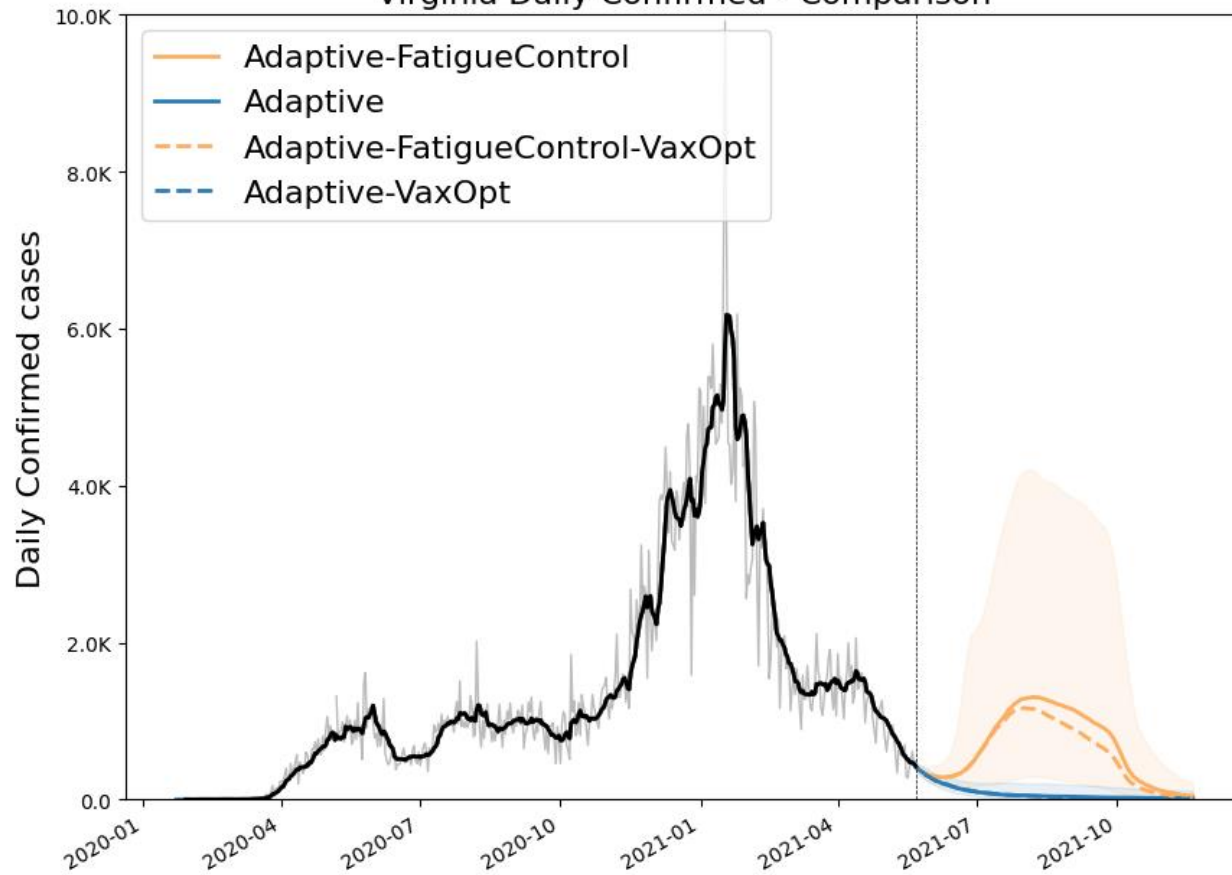
# Model Results

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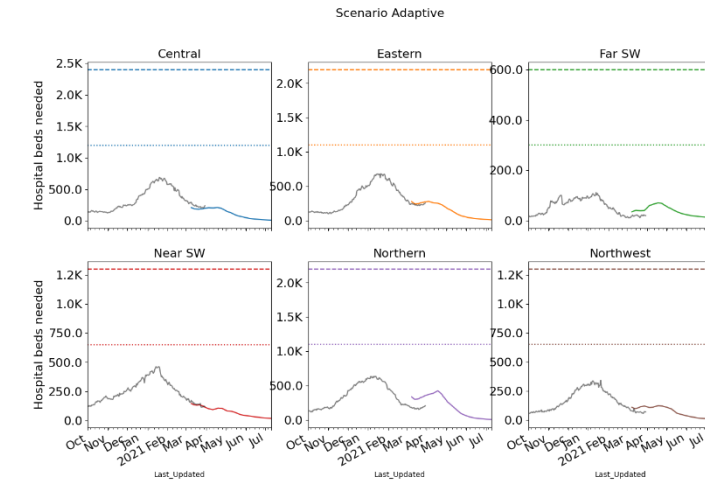
# Outcome Projections

## Confirmed cases

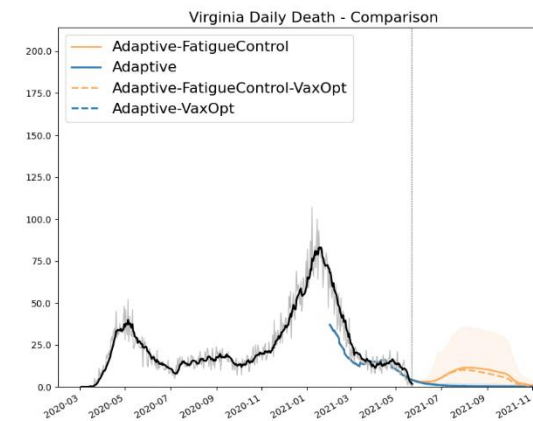
Virginia Daily Confirmed - Comparison



## Estimated Hospital Occupancy

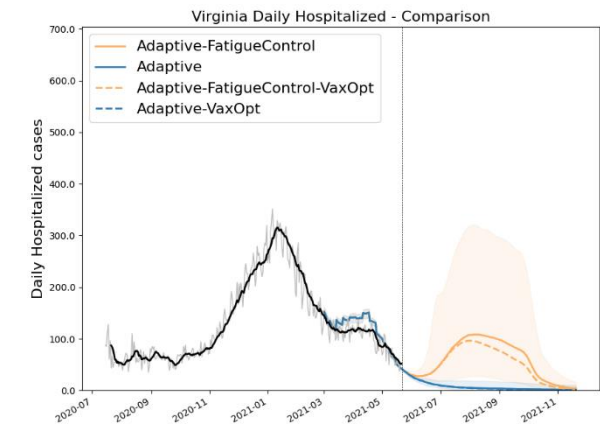


## Daily Deaths



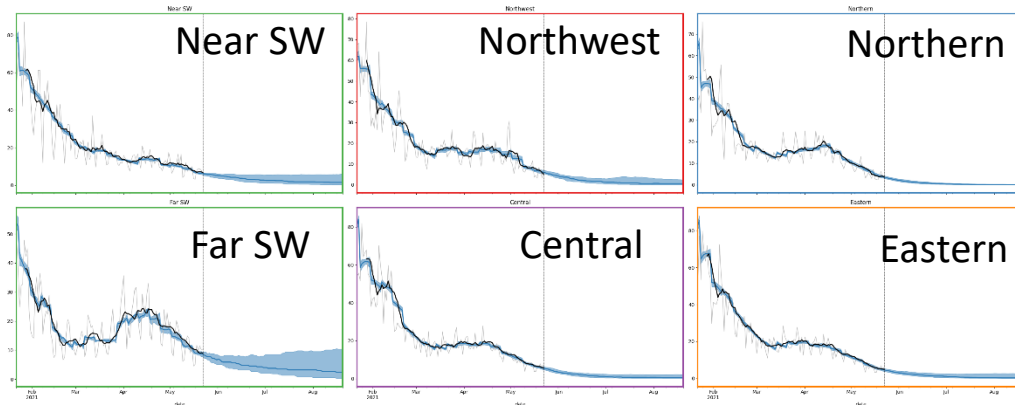
Death ground truth from VDH "Event Date" data, most recent dates are not complete

## Daily Hospitalized

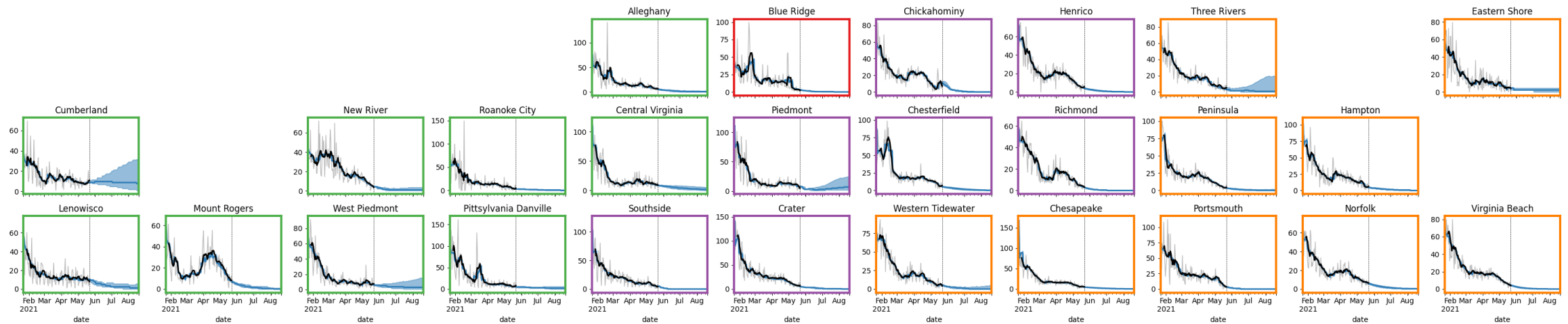


# District Level Projections: Adaptive

## Projections by Region



## Projections by District

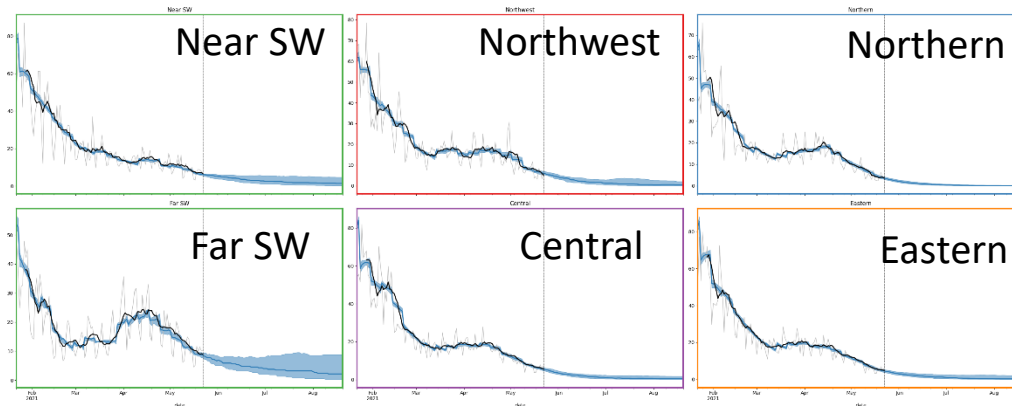


Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

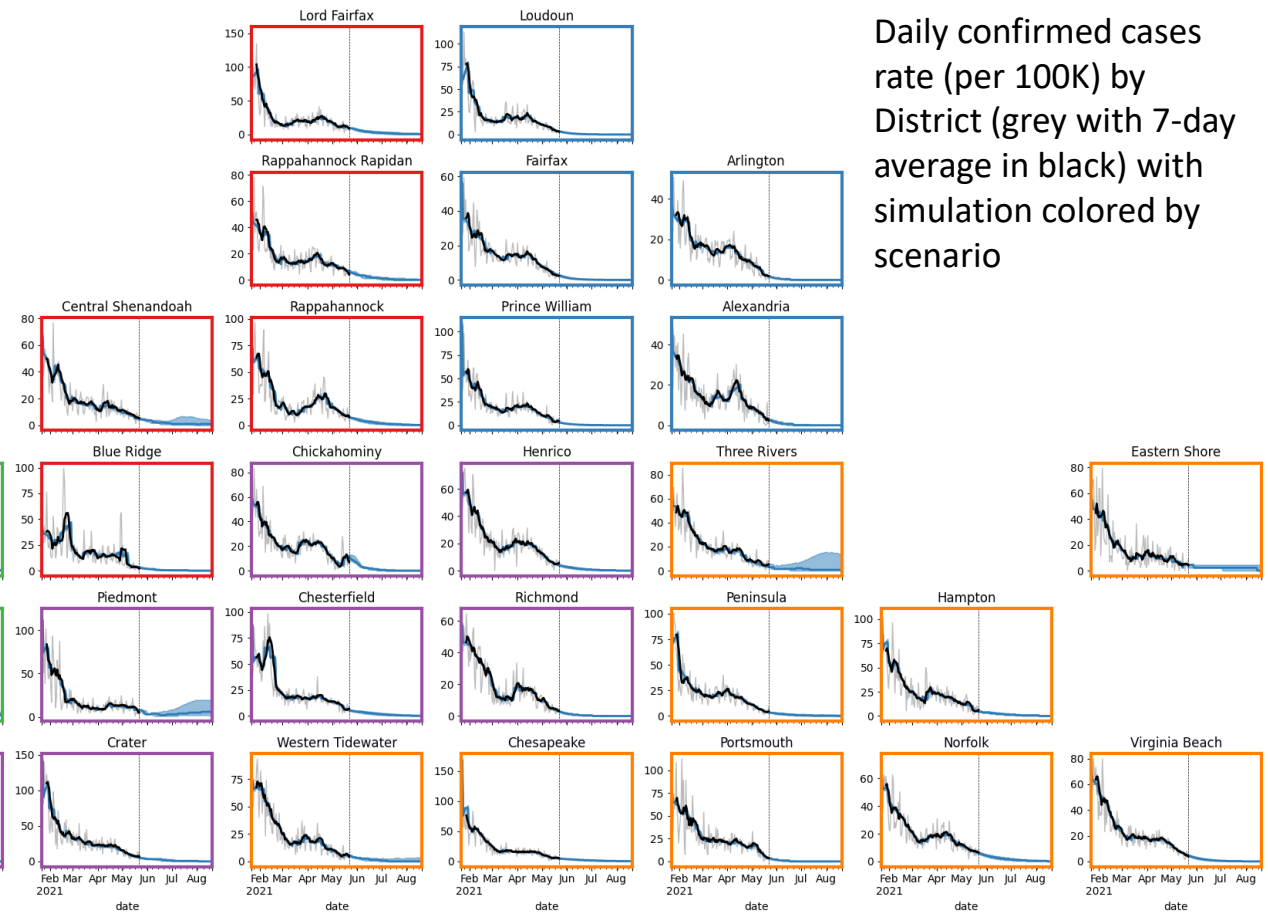


# District Level Projections: Adaptive-VaxOpt

## Projections by Region



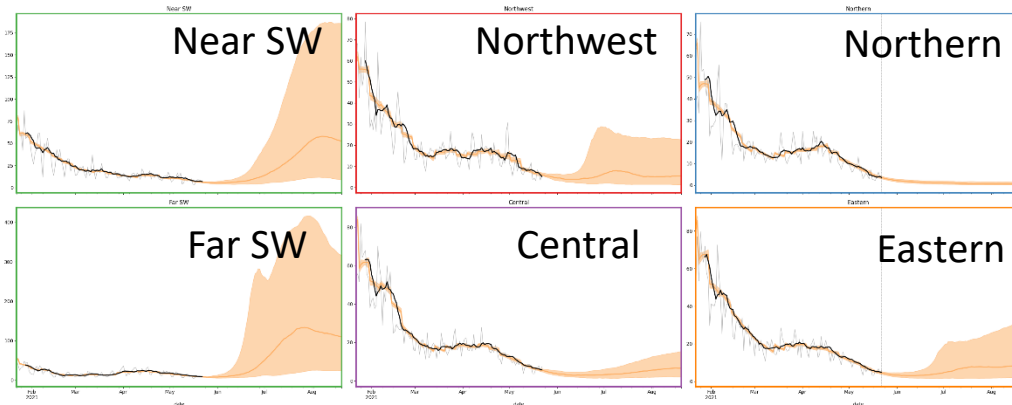
## Projections by District



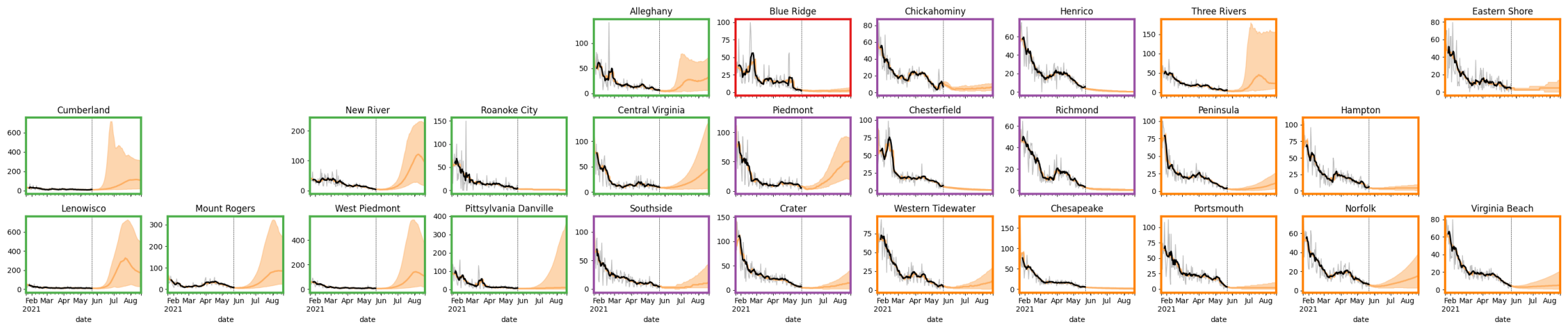
Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

# District Level Projections: Adaptive-FatigueControl

## Projections by Region



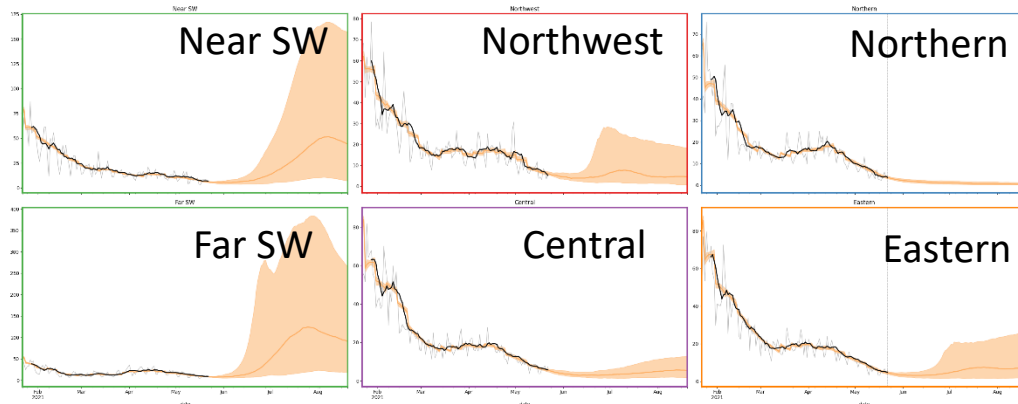
## Projections by District



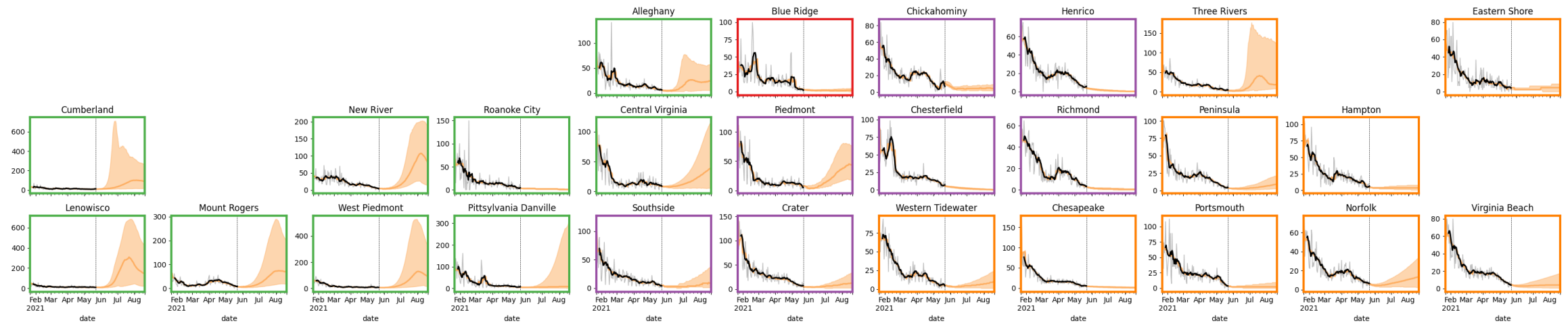
Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

# District Level Projections: Adaptive-FatigueControl-VaxOpt

## Projections by Region



## Projections by District

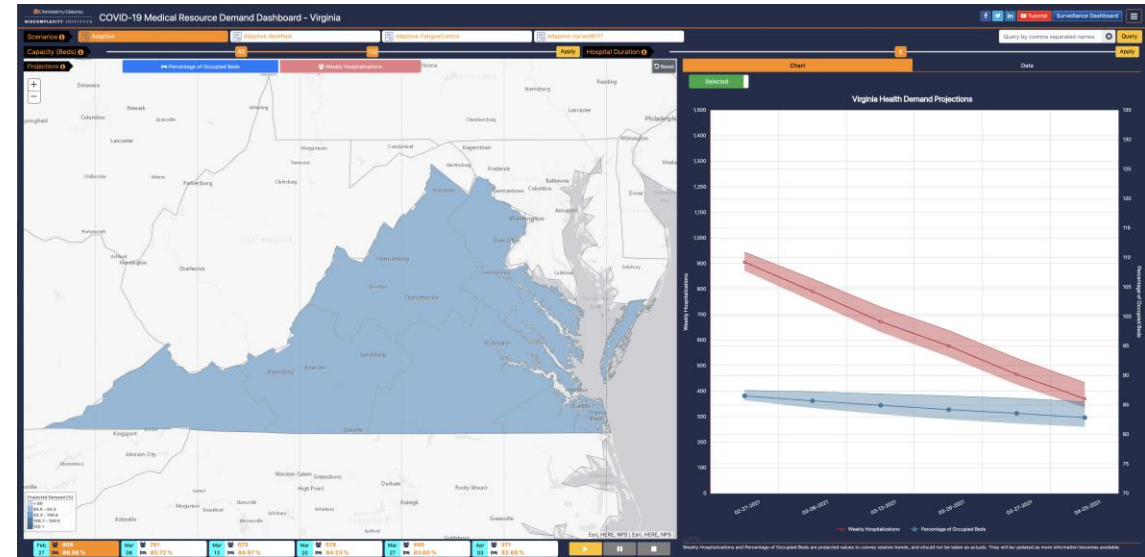
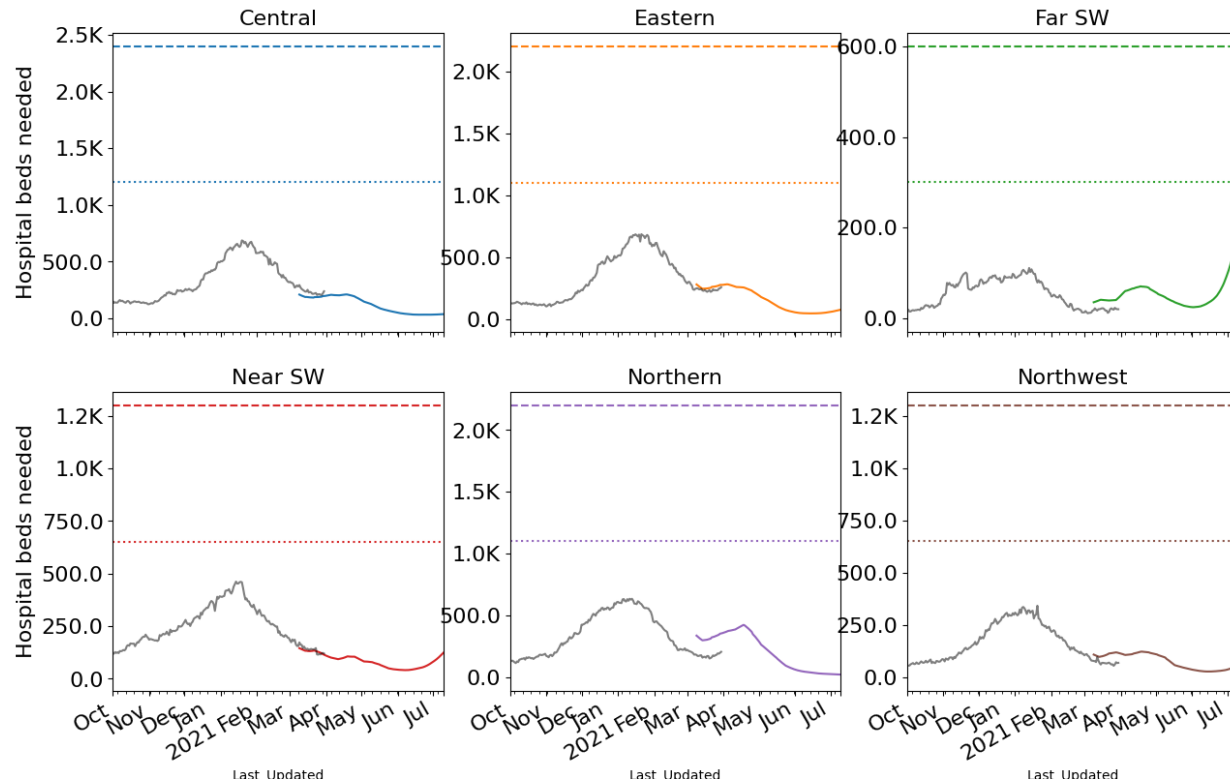


Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

# Hospital Demand and Bed Capacity by Region

## Capacities\* by Region – Adaptive-FatigueControl-DominantB117

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds



<https://nssac.bii.virginia.edu/covid-19/vmrddash/>

## If Adaptive-FatigueControl-DominantB117 scenario persists:

- No capacity challenges for hospital beds in near-term

\* Assumes average length of stay of 8 days  
26-May-21

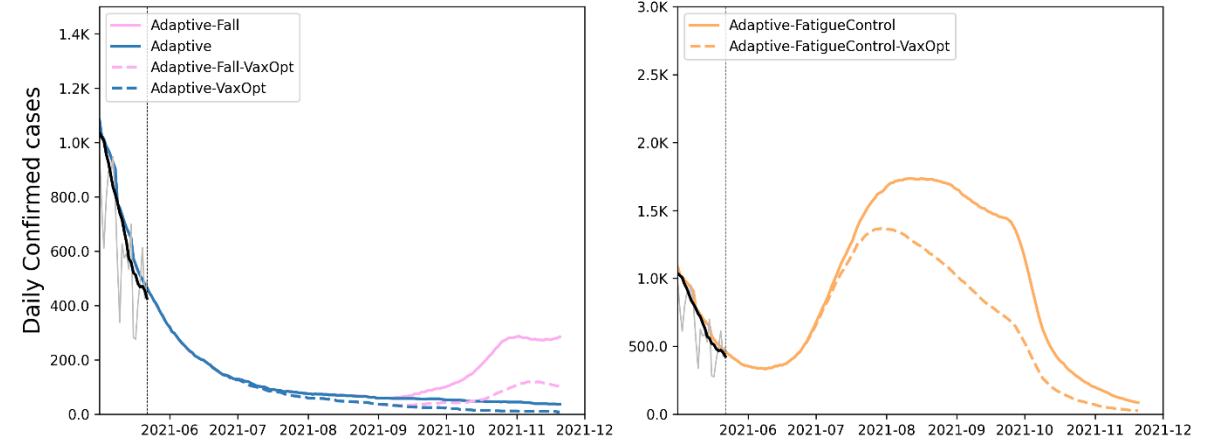
# Resilience to Potential Fall Surge

## Impact of expanded vaccine acceptance against a Fall Surge

- To further test Virginia's resilience to new transmission surges, implement a Fall Surge
  - Highest rate from Fall 2020, with a 2 week ramp up starting on Sept 1<sup>st</sup> 2021
- More highly vaccinated population more resilient to Fall Surge, with nearly 10k cases averted
- In worst case of sustained Fatigue Control 60K+ cases averted

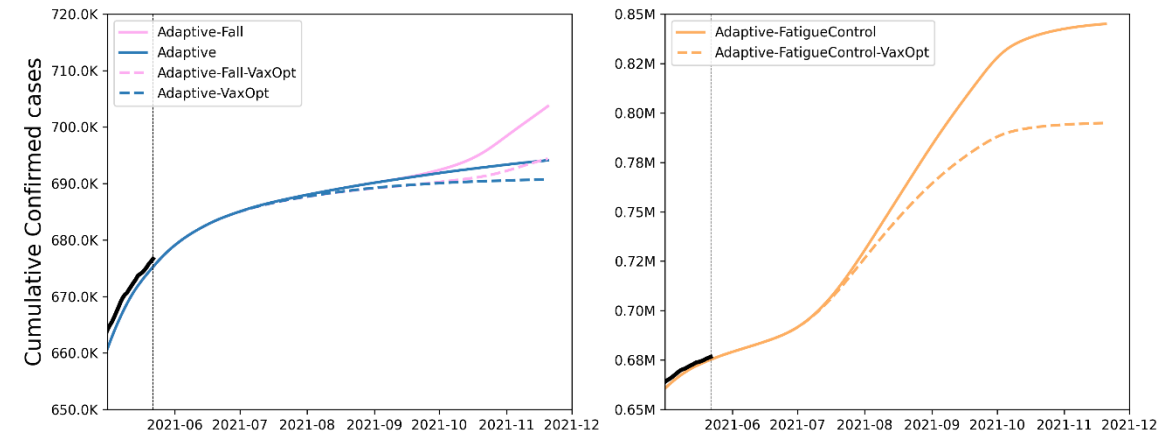
## Daily Infections

Virginia Daily Confirmed - Comparison



## Cumulative Infections

Virginia Cumulative Confirmed - Comparison

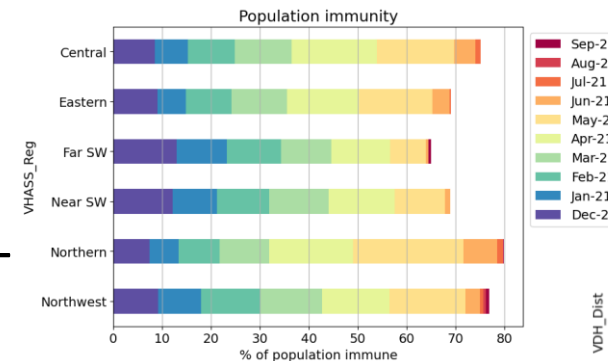




# Virginia's Progress on Population Immunity

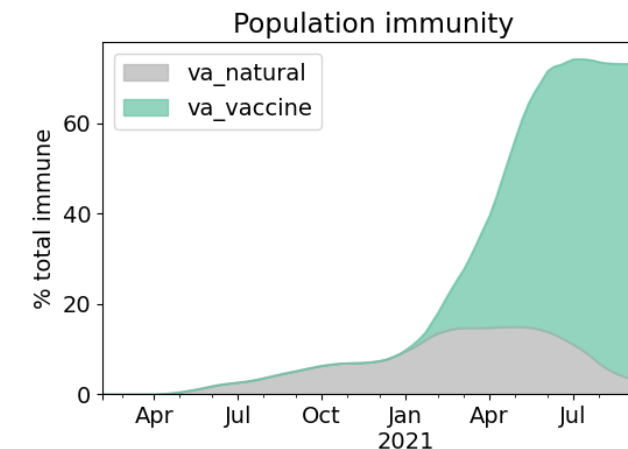
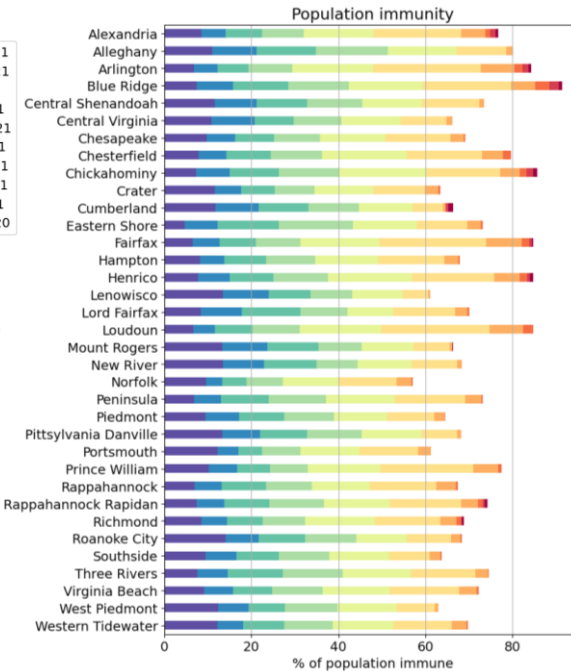
## Natural Immunity and Vaccines combine to produce a population level of immunity

- Duration of immunity from infection with SARS-CoV2 still not well understood
  - We assume a conservative 6 month period of protection for these calculations
  - Natural immunity is well calibrated to recent seroprevalence surveys
- Vaccine induced immunity is likely to last longer, we assume indefinite protection
  - This also assumes that all administered vaccines remain protective against current and future novel variants
- Population immunity depends on a very high proportion of the population getting vaccinated
  - Using regional vaccine acceptance



Region	% immune (est.)*
Central	68%
Eastern	63%
Far SW	63%
Near SW	67%
Northern	68%
Northwest	70%
Virginia	67%

\* As of May 23, 2021



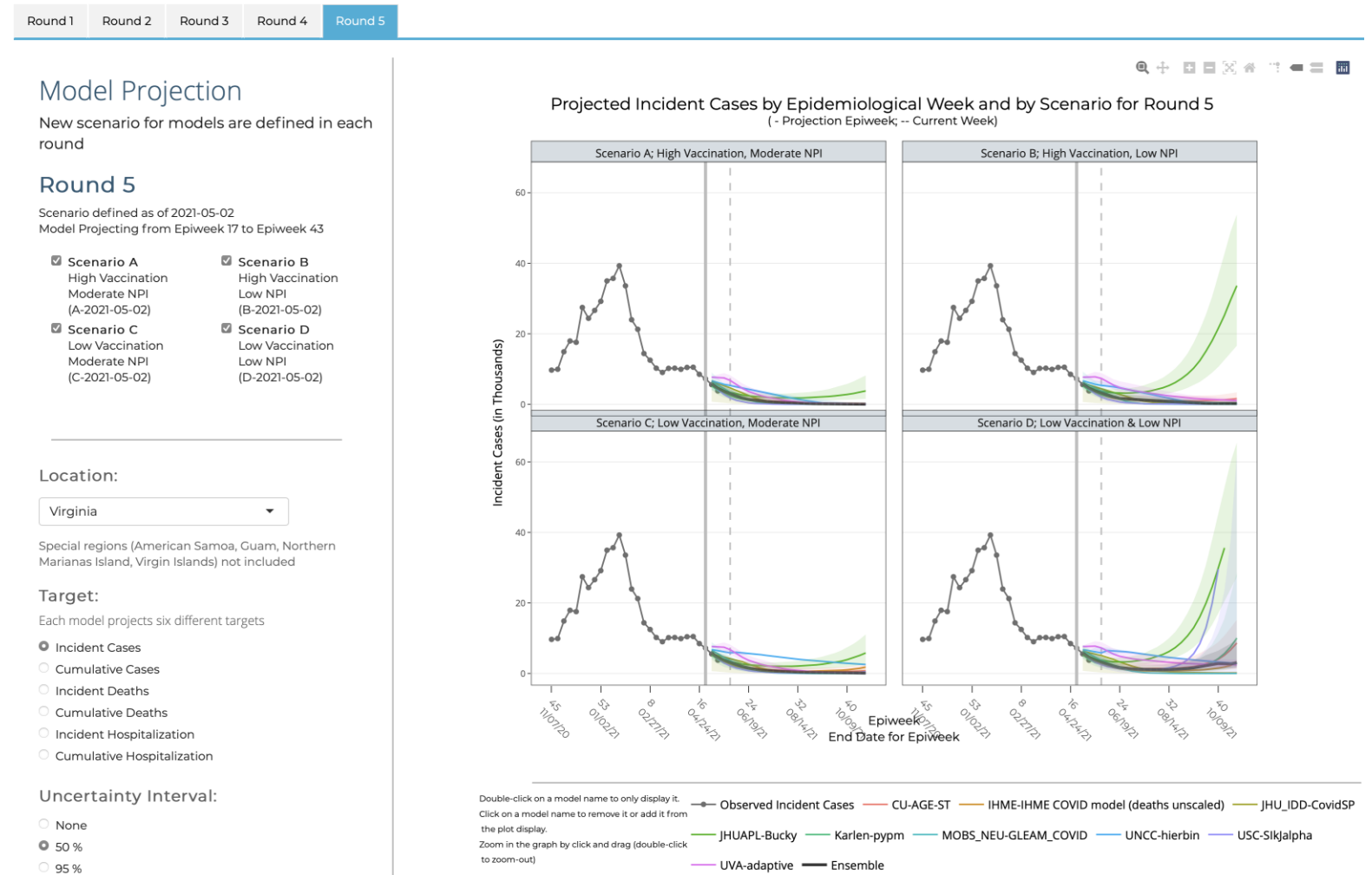
# COVID-19 Scenario Modeling Hub

Collaboration of multiple academic teams to provide national and state-by-state level projections for 4 aligned scenarios that vary vaccine rates (high – low) and levels of control (moderate and low)

Round 5 updates now available

Round 4 Results were published May 5<sup>th</sup>, 2021 in [MMWR](#)

<https://covid19scenariomodelinghub.org/viz.html>



# Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

Even without perfect projections, we can confidently draw conclusions:

- **Case rates in Virginia continue to decline with pace accelerating in some districts**
- VA mean weekly incidence down to 4/100K from 6/100K, US down (8 from 10 per 100K)
- Vaccination rates have slowed considerably, but population immunity now estimated over 65%
- Projections show declining rate overall across Commonwealth
- Recent updates:
  - Minor updates to measured acceptance levels and adjusted vaccination scenarios
  - Additional Fall resurgence study scenario testing resilience of population
  - Limited waning of natural immunity included in fit and projections, also with seroprevalence update
- The situation continues to change. Models continue to be updated regularly.

# References

Venkatramanan, S., et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints." *PLoS Computational Biology* 15.9 (2019): e1007111.

Arindam Fadikar, Dave Higdon, Jiangzhuo Chen, Bryan Lewis, Srinivasan Venkatramanan, and Madhav Marathe. Calibrating a stochastic, agent-based model using quantile-based emulation. *SIAM/ASA Journal on Uncertainty Quantification*, 6(4):1685–1706, 2018.

Adiga, Aniruddha, Srinivasan Venkatramanan, Akhil Peddireddy, et al. "Evaluating the impact of international airline suspensions on COVID-19 direct importation risk." *medRxiv* (2020)

NSSAC. PatchSim: Code for simulating the metapopulation SEIR model. <https://github.com/NSSAC/PatchSim>

Virginia Department of Health. COVID-19 in Virginia. <http://www.vdh.virginia.gov/coronavirus/>

Biocomplexity Institute. COVID-19 Surveillance Dashboard. <https://nssac.bii.virginia.edu/covid-19/dashboard/>

Google. COVID-19 community mobility reports. <https://www.google.com/covid19/mobility/>

Biocomplexity page for data and other resources related to COVID-19: <https://covid19.biocomplexity.virginia.edu/>

# Questions?

## Points of Contact

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# Supplemental Slides

# Estimating Daily Reproductive Number

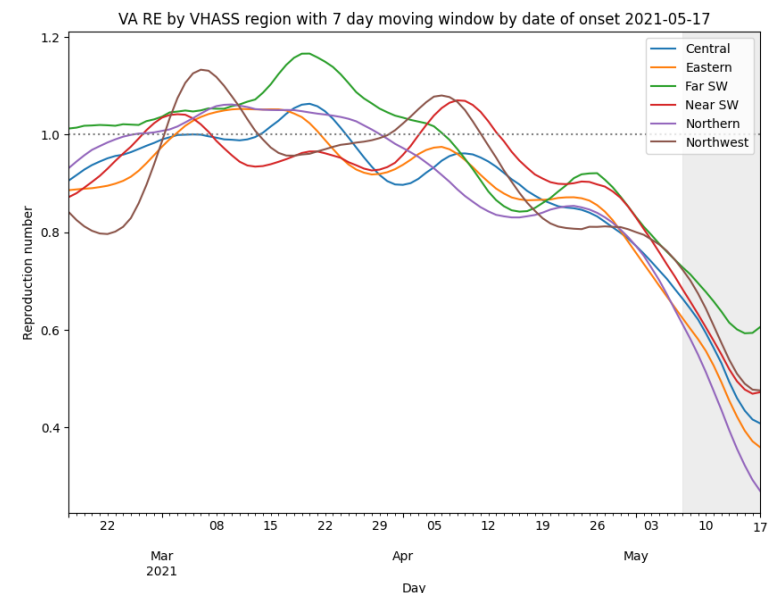
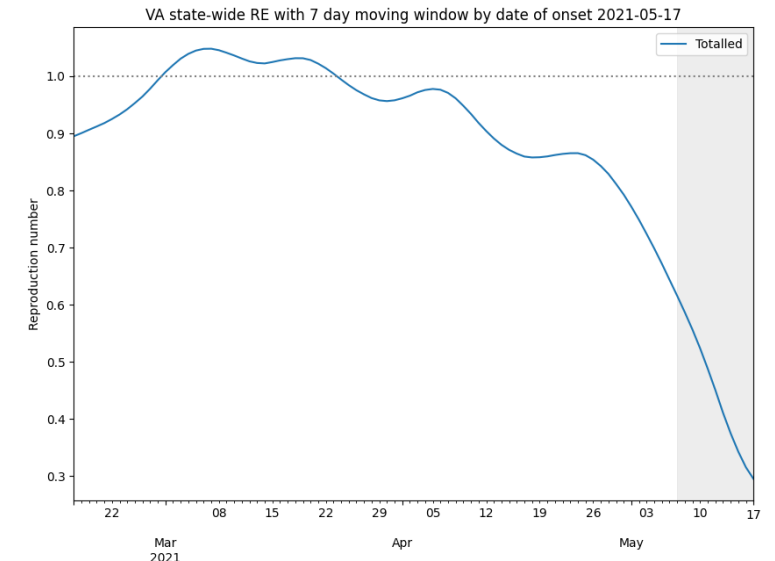
## May 8<sup>th</sup> Estimates

Region	Date of Onset $R_e$	Date Onset Diff Last Week
State-wide	0.587	-0.038
Central	0.643	-0.040
Eastern	0.602	-0.073
Far SW	0.714	0.053
Near SW	0.658	-0.052
Northern	0.581	-0.061
Northwest	0.701	0.039

### Methodology

- Wallinga-Teunis method (EpiEstim<sup>1</sup>) for cases by **confirmation date**
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, <https://doi.org/10.1093/aje/kwt133>



# Weekly Cases and Hospitalizations

Weekly confirmed cases

Week Ending	Adaptive	Adaptive-Fatigued Control	Adaptive-VaxOpt	Adaptive-Fatigued Control -VaxOpt
4/25/21	9,598	9,599	9,597	
5/2/21	9,747	9,767	9,850	
5/9/21	8,858	8,894	9,683	
5/16/21	8,048	8,086	10,150	
5/23/21	7,392	7,428	11,250	
5/30/21	6,713	6,561	13,152	
6/6/21	5,994	5,553	16,388	
6/13/21	5,365	4,521	21,163	
6/20/21	4,746	3,508	27,038	

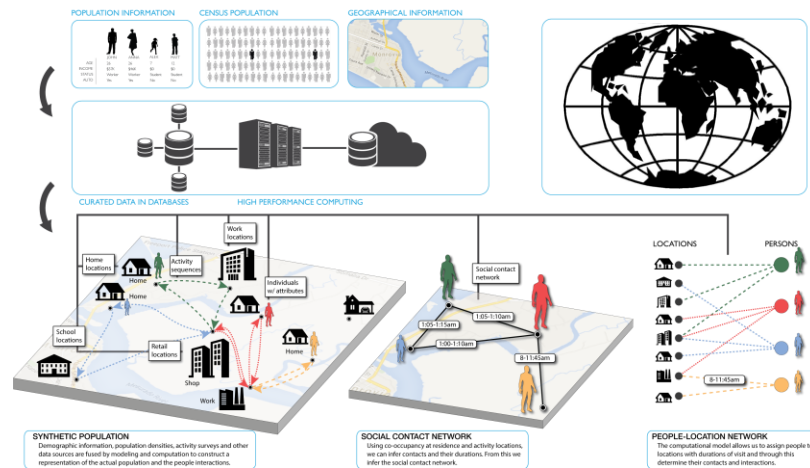
Weekly Hospitalizations

Week Ending	Adaptive-DominantB117	Adaptive-BestPast-Dominant B117	Adaptive-Fatigued Control - DominantB117	
4/25/21	750	750	750	
5/2/21	659	659	666	
5/9/21	548	548	601	
5/16/21	451	452	575	
5/23/21	373	372	580	
5/30/21	302	292	609	
6/6/21	241	219	654	
6/13/21	196	159	707	
6/20/21				

# Agent-based Model (ABM)

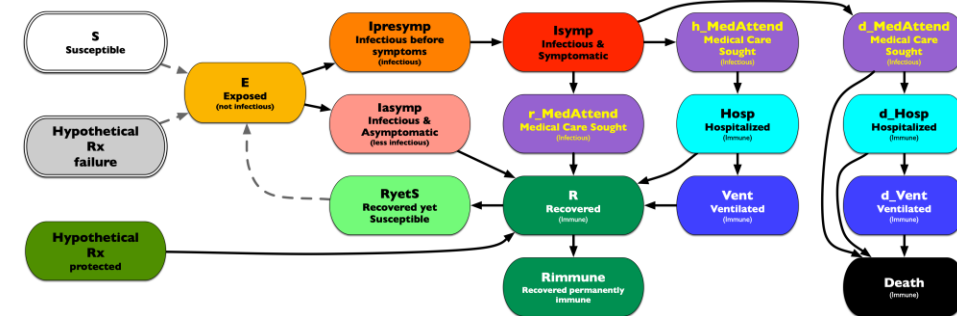
## EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing



### Synthetic Population

- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations



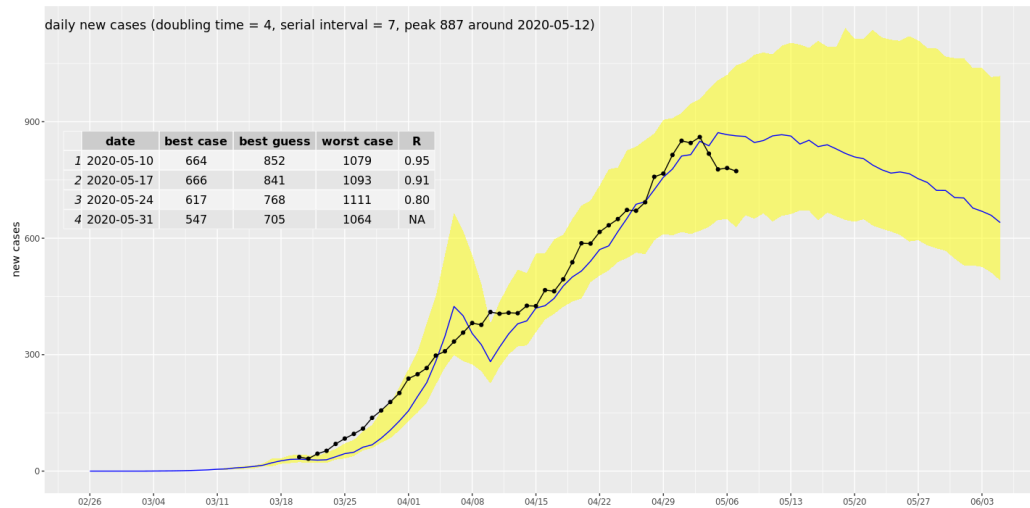
### Detailed Disease Course of COVID-19

- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments

# ABM Social Distancing Rebound Study Design

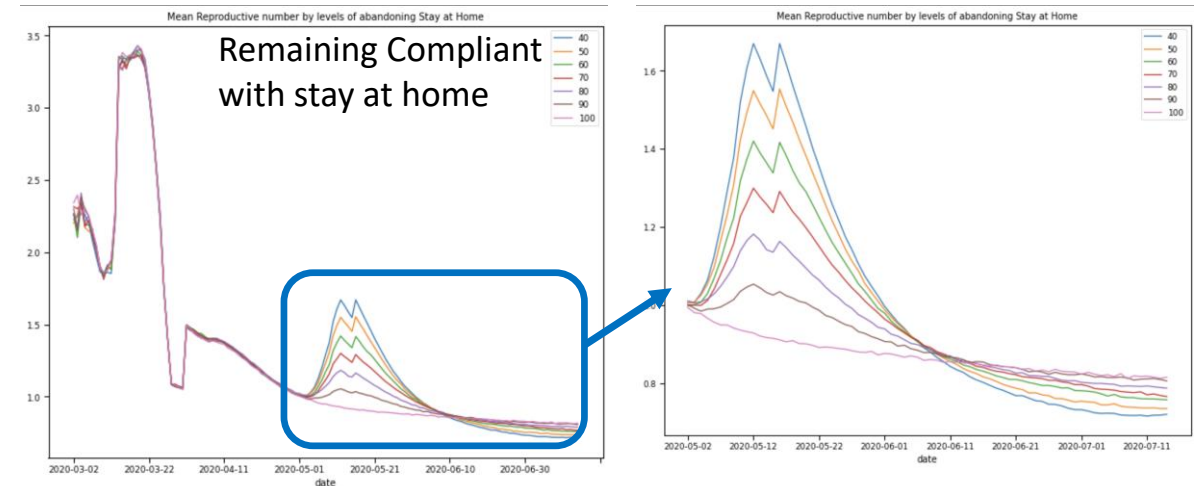
## Study of "Stay Home" policy adherence

- Calibration to current state in epidemic
- Implement "release" of different proportions of people from "staying at home"



## Calibration to Current State

- Adjust transmission and adherence to current policies to current observations
- For Virginia, with same seeding approach as PatchSim



## Impacts on Reproductive number with release

- After release, spike in transmission driven by additional interactions at work, retail, and other
- At 25% release (70-80% remain compliant)
- Translates to 15% increase in transmission, which represents a  $1/6^{\text{th}}$  return to pre-pandemic levels